METALLURGIA

THE BRITISH JOURNAL OF METALS

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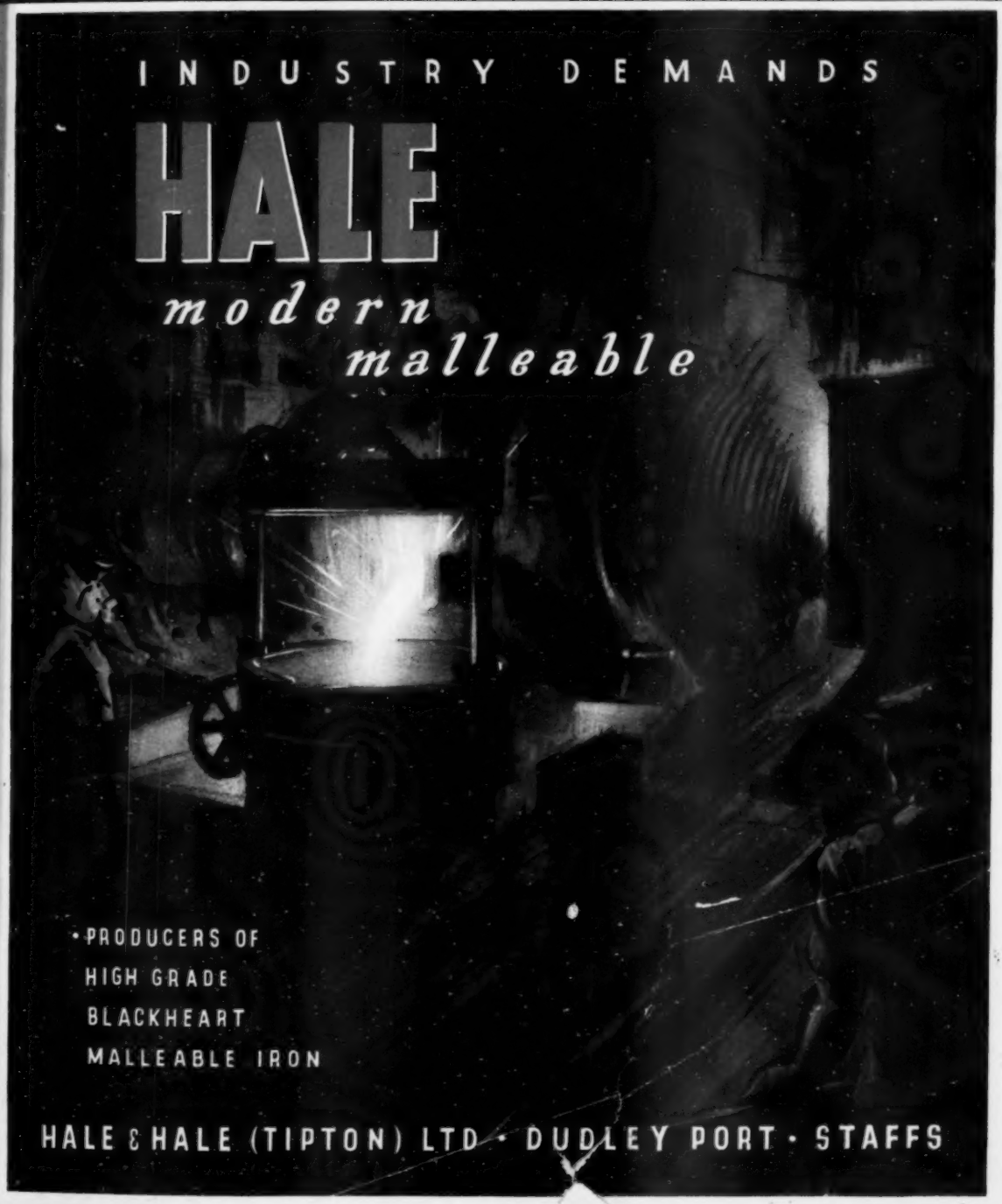

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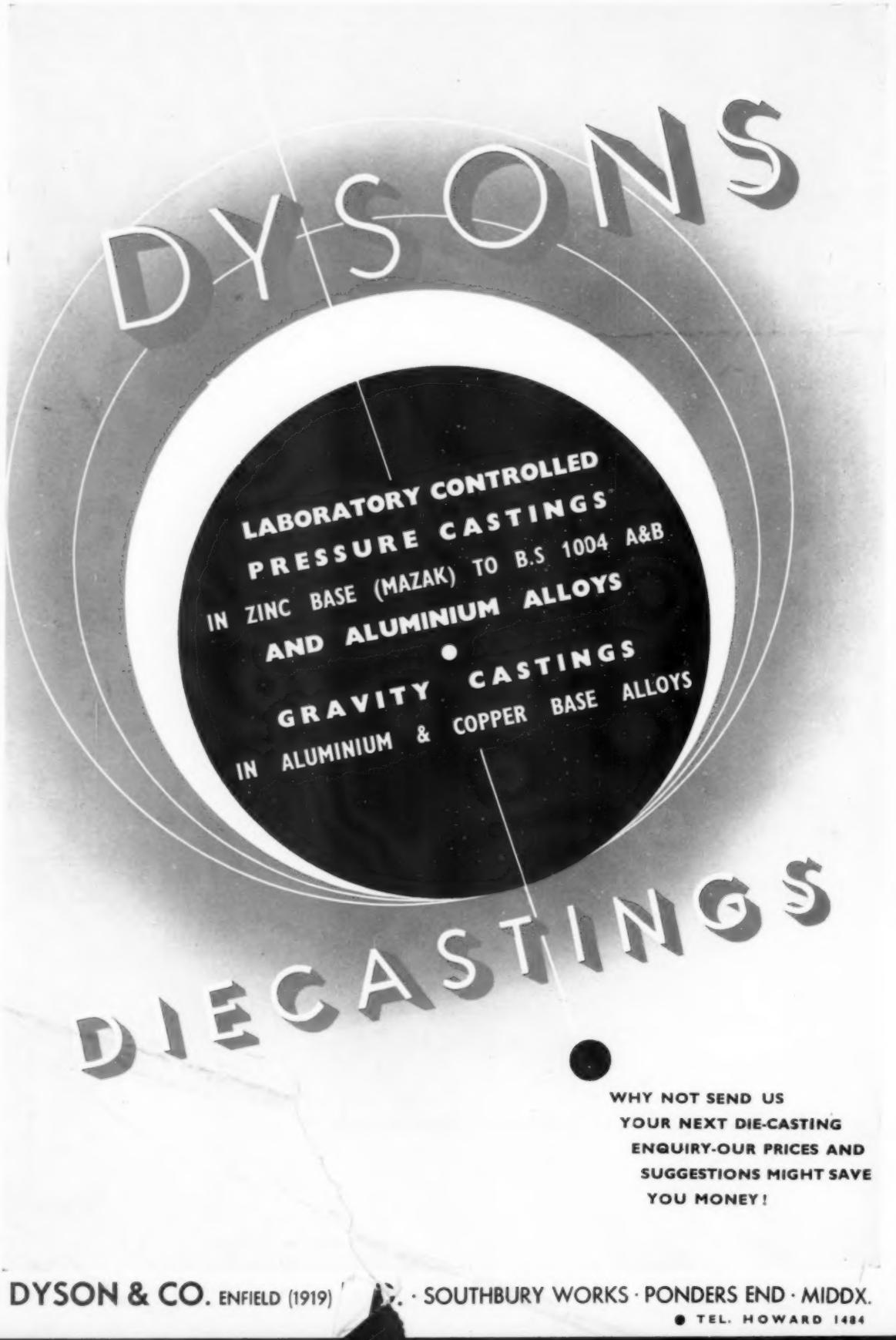
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THE BRITISH JOURNAL OF METALS
INCORPORATING THE METALLURGICAL ENGINEER

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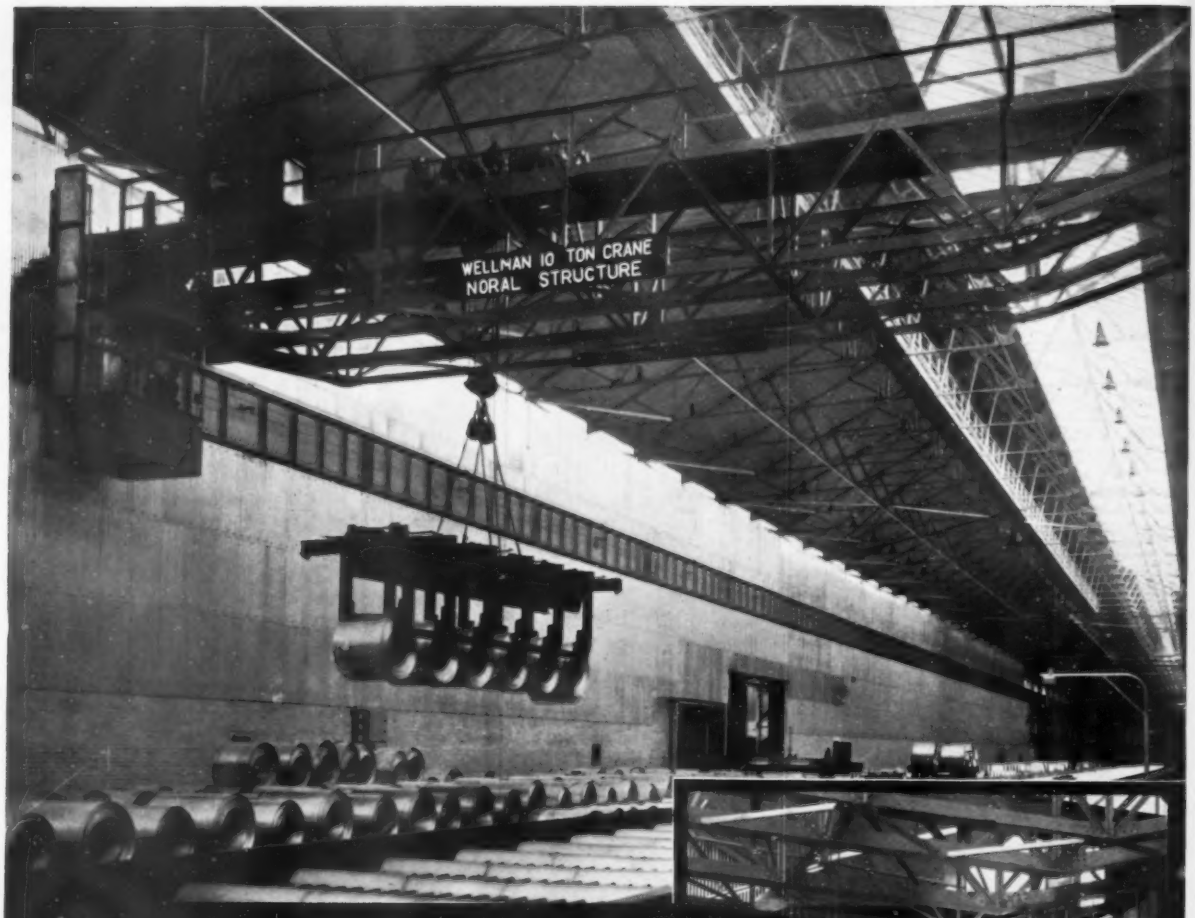

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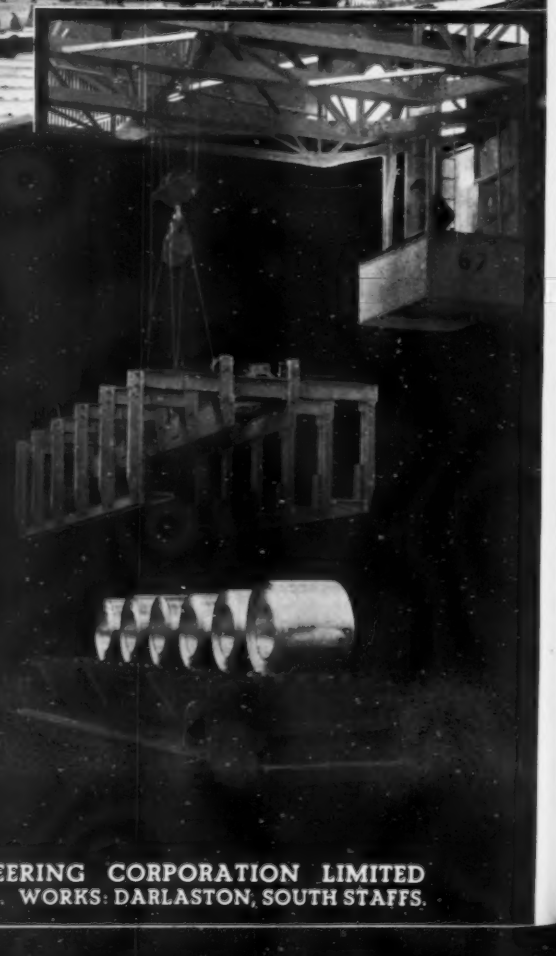

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METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

FEBRUARY, 1953 Vol. XLVII. No. 280

Steel Supply Improvement

THERE is something fascinating in forecasting the future, as witness the tremendous interest in football pools. It would be idle to pretend that the possibility of financial gain is not the main attraction, but there is a certain amount of satisfaction to be gained from being found to be right. Selection by means of a pin may win dividends on the pools, but guesswork just isn't good enough in assessing future business prospects. In such cases, certain of the governing factors are known, and past experience and basic knowledge help to minimise the uncertainty of others. It is always of interest, however, to see whether events proved the assessment to be substantially correct, and if not, to analyse the factors responsible.

At the beginning of each year, the Iron and Steel Federation summarises the progress made by the iron and steel industry during the previous year, and sets out the prospects for the ensuing twelve months. At the beginning of 1952, the Federation view was that the best that could be hoped for as regards total receipts of scrap was to maintain the 1951 figures or, more conservatively, to secure some 100,000 tons less than in that year. Accordingly, to reach an output of 16 million tons of steel, pig iron output would have to increase by at least a million tons, of which 570,000 tons would be needed to make good the contribution from stocks of raw materials in 1951 and the balance to bring production up to the 16 million mark. On such a basis, there would be no further draw on stocks of raw materials, but, on the other hand, no provision would be made for increasing such stocks. Supplies of steel to home users would depend on the level of imports and exports, as well as on production, but if 1½ million ingot tons of imports were secured in 1952, and exports were limited to 2½ million ingot tons, the supply of steel to the home market (including about 500,000 tons of re-processed material) should be about 15¼ million tons as against 14¾ million tons in 1951.

How accurate was this forecast? The total output of pig iron and blast furnace ferro-alloys was raised from 9,669,000 tons in 1951 to some 10,730,000 tons in 1952. This includes foundry pig iron, the steelworks' consumptions being 7,794,000 and 8,650,000 respectively. In addition, the steelmakers increased their pig iron stocks by about 330,000 tons, to offset the 200,000 tons reduction the previous year. The scrap position was a little better than had been expected, the continuance of the scrap drive helping to raise the supply of home-bought scrap appreciably above that of 1951. The steelmakers themselves found about 270,000 tons over and above normal "own arisings," and with imports and circulating scrap showing slight increases, it was possible to use some 275,000 tons for rebuilding the industry's stocks, which were depleted by 323,000 tons in 1951. The scrap actually used in steelmaking showed a slight decline, from 9,124,000 to about 9,080,000 tons.

The output of steel ingots and castings rose to 16,430,000 tons in 1952, and although this figure covers 53 weeks, the figure for 52 weeks, 16,138,000 tons, would still have exceeded the 16 million tons forecast. To supplement the increased supplies from home sources, imports of ingots and semi-finished steel were very considerably increased last year to some 1,800,000 tons as against 560,000 tons in 1951, whilst exports were again held down to 2,600,000 tons, compared with 3,250,000 in 1950, the peak post-war year. As a net result, the supply of steel to the home market was estimated to be 15,880,000 tons.

The all-round improvement over 1951 was based entirely on higher pig iron consumption, which was made possible by the increase in blast furnace capacity which became available during the year as a result of provisions made in the Development Plan. Six new or rebuilt blast furnaces were blown in during 1952, and a further one was scheduled to go into operation early this year. To feed the new furnaces, more than 3 million tons of additional iron ore had to be provided, and extra ore preparation and sintering facilities have been brought into operation to make the best use of this material. Home ore consumption has been raised from 14 to 16 million tons, while the imported ore used has been stepped up from 7¾ to over 8¾ million tons; these figures exclude ore used in steelmaking.

So much for the past—what of the future? Although there is a possibility that there may be slight shortages in one or two special classes of steel, there would seem to be no reason why any desirable programmes for exports or capital investment should be limited by shortage of steel during the coming year, for supplies have been expanding rapidly in recent months, and a further considerable increase is in prospect.

As the industry derives the full benefit from the new blast furnaces completed in recent months, pig iron production should rise by about a million tons in 1953, as compared with 1952. Steel production will benefit, not only from the larger supply of pig iron and the automatic increase in circulating scrap, but also from the fact that there will be no need to replenish stocks of steelmaking materials, as was the case last year. It should, therefore, be possible for the industry to reach the production objective of 17½ million tons which it has set itself for 1953. During the past year, moreover, the stocks of producers, merchants and consumers are estimated to have increased by some 500,000 ingot tons. Thus the prospective increase in available supplies during the coming year may be of the order of 2 million ingot tons—which should be more than ample to meet the requirements of all programmes at home. It should be sufficient to permit some reduction in the rate of import and a moderate increase in direct exports over the restricted levels of the last two years.

Correspondence

SHELL MOULDING PATENTS

The Editor, METALLURGIA.
Sir,

We would compliment Dr. Voce on his excellent survey of the progress in Copper and Copper Alloys during 1952. Shortage of space has, however, rendered the statement on the patent position in shell moulding somewhat ambiguous.

It is stated that "The Patent situation has to some extent been clarified by a statement issued in the United States and reproduced in this country. It would appear that valid patents can now be granted on specific improvements only, and not on the basic process as such. In this country patents by the Polygram Company cover several methods of producing suitable patterns and other details of technique." This would be much clearer if the words "in the United States" had been inserted after "can now" in the above statement. The source quoted did, in fact, make it clear elsewhere that this pronouncement is valid *only in the United States*. This is largely because no patents on the basic process were filed in the States prior to the publication of the F.I.A.T. Report which put shell moulding "in the public domain" in the U.S.A. In this country and elsewhere, however, patents covering certain features of the *basic process* were filed before the issue of this Report. It is, therefore, clear that the pronouncement made in the United States is by no means necessarily applicable in this country. The policy of my company is, however, completely unrestrictive and licences will be readily available to cover both existing patents and any future patents which may be granted to Polygram.

Yours faithfully,
J. FALLOWS,
Technical Director.
Polygram Casting Company Limited

London.
27th January, 1953.

MACHINE TOOL FINISH

The Editor, METALLURGIA.
Sir,

Wide publicity has been given both in the Press and by the B.B.C. to the recommendations of the British Productivity Council in their Report on Machine Tools, particularly that which proposes the cheapening of machine tools by reducing the quality of the finish. It should, therefore, be as widely realised that it is essential for machine tools to be well-finished, for the following reasons:

(1) That the finish protects the tool against corrosion, etc., and therefore prolongs its life.
(2) That a smooth paint finish and bright polished plated ware enable the machine to be kept clean and therefore to produce better work.
(3) That a well-finished machine has a psychological effect on the operator who takes more care of it, increasing its useful life and also producing a better product.
(4) That in any market a shoddy finish is likely to give the impression of a poor machine and the chances of a sale in competitive markets would be correspondingly reduced.

The recommendations on page 49 of the Report that a return should be made to war-time finish, e.g., a coat of grey paint on an unfilled casting, would be likely to have serious repercussions on our export trade in particular (amounting to over 40% of British production); furthermore, it would adversely affect the useful life of the machine and probably its productive power. While such measures were necessary during the war, to revert to them in peace time would most certainly not be in the national interest.

Yours faithfully,
S. WERNICK.
Hon. Secretary, Institute of Metal Finishing
London.
27th January, 1953.

Making Science Work

AT the annual luncheon of the British Industrial Measuring and Control Apparatus Manufacturers' Association (BIMCAM) in London, last month, Sir Charles Ellis, F.R.S., a member of the National Coal Board, said the industry could be proud of the way in which it had grappled with changing events; the speed with which the research instrument was developed and made into a production instrument was a remarkable achievement. More and more basic industries were realising the importance of measurement rather than guesswork, and were following the lead of the most modern industries in application of the principle that "to measure is to know."

Sixty-two members of BIMCAM and their guests heard Mr. W. G. Ardley, President, propose the toast of "The Guests," to which Sir Charles Ellis replied. Mr. L. S. Yoxall, Chairman of the Association, expressed disappointment with the terms of the £1m. scheme for Government loans to industry to increase fuel efficiency. It was common knowledge that measuring instruments would give a greater fuel return than almost any other type of equipment. Despite this, measuring and control apparatus had not been included in the Government list of equipment qualifying for the loans. In addition, the amount of the loans envisaged was inadequate.

Mr. E. B. Moss, President of the Society of Instrument Technology, proposing the toast of BIMCAM, referred to the way in which large sums could be saved by the provision of instructional literature of a high standard. These instructions, supplied by instrument manufacturers, dealt with the installation, maintenance and servicing of their equipment, and great attention was paid to this point in the U.S.A. He even hazarded the opinion that poor instruments could be made acceptable if they were accompanied by good literature, though this was denied by Mr. Yoxall, who stated that good instruments needed no literature at all.

Mr. Ardley welcomed new members of the Association: Messrs. British Pitometer Co. Ltd., Drayton Regulator and Instrument Co. Ltd., and Sunvic Controls Ltd. The 27 firms now in BIMCAM represent more than 90% of the productive capacity of the industrial instruments industry in Great Britain.

An important activity of BIMCAM this year will be the organising, with related associations, of the 2nd British Instrument Industries Exhibition at Olympia from June 30th to July 11th, 1953.

Maintenance in Iron and Steel Works

Conference on Important Aspect of Productivity

The sixth conference called to consider particular aspects of the Iron and Steel Industry Productivity Report was concerned with engineering maintenance, for which the labour consumption rates are better in the U.S.A. than in this country. Five members of the Productivity Team attended the conference, and three of them, including the leader, Sir Charles Goodeve, presented papers for discussion.

ENGINEERING maintenance in the iron and steel industry was the subject of a conference organised by the British Iron and Steel Research Association shortly before Christmas. Mr. J. F. R. Jones (John Summers & Sons, Ltd.) was in the Chair, and the 129 delegates who attended were drawn from both iron and steel firms and plant manufacturing firms. There were five members of the Productivity Team on Iron and Steel present.

The conference had been, as Sir Charles Goodeve put it, " catalysed " by the report of the Productivity Team on the iron and steel industry. Discussion was by no means restricted to the points made on this subject by the report, but its observations on the lower ratio of maintenance man-hours to productive man-hours in American plant than in British, despite generally harder driving in America, formed a background to the whole of this very workmanlike conference.

Sir Charles Goodeve opened the conference on a general note. He suggested that if maintenance (a very costly process) were to be carried out with the maximum economy, it was necessary to arrive at some means of expressing the cost of down-time plus the cost of maintenance per ingot ton. This, in turn, could be broken down for the individual parts of the plant. In short, how was maintenance work to be expressed quantitatively ? A solution to this problem would be a considerable help to the industry in its efforts to overhaul American maintenance results. The reasons for their frequently better showing were, he thought, probably newer plant in the U.S.A. and " a little more foresight in the layout of the plant."

Plant Recommendations

MR. BASIL GRAY (English Steel Corporation, Ltd.), speaking on " Plant Recommendations for the Future," confined his remarks largely to cranes, which he pointed out " cause more than half our mechanical maintenance." He thought that valuable lessons could be learned from motor car design and manufacture. " The designer of the ordinary mass production car," he said, " having made every effort to ensure that sudden failure will not occur, cannot afford to make every part last as long as possible, since the additional cost of materials and manufacture, and the loss in performance owing to the extra weight, would be prohibitive. He therefore sets up a target for the time for which the car should last without major repair, and it is a fault in design if, at the expense of manufacturing cost or performance, any part lasts longer than the specified period."

In a recent quotation for a standard crane with totally enclosed gears and roller bearings, the price and weight were less than half those in two other quotations to a standard steelworks specification. Some of the difference was because the one crane saved weight by not using mill-type motors and by using roller bearings, so that the power required was less than half that required for the heavier crane. " Such a crane," he said, " must occasionally sustain shocks and stresses as severe as the steelworks crane, but much less frequently, and there is no doubt that it would give efficient service for a time even under the worst steelworks conditions, but it is certain that it would not last long. In fact it is a similar case to the mass produced car."

The most useful function of theoretical investigations of service conditions was to introduce corrections " not by a factor of safety, but a factor of wear and tear, based on experience, whose value would largely depend on the frequency of the occurence of the particular combination of stresses in service, and might in some cases be less than unity." B.I.S.R.A.'s work on detailed examination of stresses in structures was a case in point, which he hoped would be used to the full in improving designs.

Cranes developed on these lines could be regarded as complete assemblies and completely removed for overhaul. For this to become possible, however, electrical wiring arrangements would have to be improved. Why should there not be arrangements by which it would be possible to plug in in a few minutes, instead of having men " hanging on by their eyelids " to connect up all resistances, etc., separately.

Concluding, Mr. Gray said that maintenance engineers should be brought into discussions on the design of new plant from the very beginning. He also urged that plant manufacturers should be fully informed, not only about teething troubles but also about lessons learned from the first major overhaul.

Discussion

Another member of the Productivity Team, commenting on American maintenance records, pointed out that, in the U.S.A., mills were shut for maintenance in rotation, in contrast to the British practice of carrying out most maintenance at weekends. This made for fuller employment of maintenance staff, and avoided premium payments for Saturday and Sunday working. Another point was that British figures often had to include the heavy burdens of maintenance of ore crushing plant, a process which was usually carried out at the ore quarries in America. Several speakers took up the point of rotational maintenance. One speaker said that his firm had found it worth while, especially in melting shops operating the continuous working week, to go further and to purchase a new crane or a new charger and put it up and then arrange to take down one crane or one charger at a time and remove it for overhaul.

Sir Charles Goodeve recalled how a scientist engaged during World War II to examine maintenance organisation in the R.A.F. had plotted engine fault frequency against time since last overhaul, taking some thousands of overhauls and aircraft histories as data. By studying the resulting curves he was able to show that "the maintenance organisation had been so cautious that they were overhauling their aircraft at least twice as often as necessary. They thereupon, as a result, doubled the total number of flying hours of each aircraft between maintenance and raised the availability from 30% to almost 60%." This experience was being applied by the London Transport Executive for buses, and while the principle could be used only when the number of examples was large, and would be impossible to apply to a rolling mill, it was of interest and might prove valuable to the steel industry.

The difficulty of quantitative measurement of maintenance was commented on by several speakers. Not only downtime resulted from inadequate maintenance, but slow operation of plant as well, and this was difficult to evaluate. Another point was that abuse of plant by ignorance or accident (as by the rolling of a cold ingot) should not be debited against maintenance costs. It seemed to be generally agreed, however, that "buck passing" should be avoided at all costs, and that the use of some quantitative "bogey" to provide an incentive to cheapen and improve maintenance could often be of considerable value. One speaker emphasised the importance in this connection of having systems of record-keeping and costing in a form which enabled managements and engineers and everybody else concerned to put a cash value on what was being done in maintenance. This speaker had had the maintenance costs of a series of separate rolling mills worked out per ton of finished product as a standard of comparison.

Another point that seemed to meet general agreement was the desirability of associating the maintenance engineers with discussions on new plant design at the earliest possible stage. One delegate from a firm of plant manufacturers said that in one plant installed in this country since the war, where co-operation with the maintenance engineers was complete, the down-time for mechanical maintenance had been less than 0·1%. The same speaker suggested that when the production engineers had complete control over the design, they tended to insist on the most complicated automatic gear and interlocking devices to reduce production man-power costs. They did not always realise that in all probability they were increasing their maintenance costs. Other speakers suggested that maintenance engineers brought in at an early stage might improve design in such matters as accessibility, and in the avoidance of breakdowns by reducing stringent specifications as, for example, in the speed of crane hoists.

In connection with design and manufacture, Mr. Gray's point on the application of theoretical investigations of service conditions to introduce "factors of wear and tear" was commented on by two speakers, one a plant manufacturer. Both thought that B.I.S.R.A.'s work on the measurement of roll force and torque in rolling mills must inevitably lead to the design of plant more nearly to fulfil exact requirements. "Mill builders," said the plant manufacturer, "are beginning to realise that there is a great possibility of lightening designs. But their main difficulty is going to be in getting the mill user to accept these. Users will have to accept the theories of B.I.S.R.A. wholeheartedly and accept a type of design based on those theories, forgetting completely the enormous mills which they have seen in America."

Other points touched on during the discussion were the importance of careful inspection during construction and installation of plants and the value of cleanliness and good lighting in maintenance. The desirability of standardising spares, especially for cranes, was urged by several speakers, though others expressed anxiety that this might prejudice enterprise and the exploration of new designs.

Relationship between Production and Maintenance

Mr. A. Bridge (Appleby-Frodingham Steel Company) opened the afternoon session with a paper on the "Relation of Production and Maintenance Departments." The first essential was for both sides to understand clearly that they had a common objective, in achieving which they were equal partners. That objective was "to produce the maximum output with the minimum of interruption consistent with quality of end product."

Maintenance, at once a service and a key to production, was no longer a necessary evil, called in only to remedy a breakdown. A modern integrated plant was like one huge and complex machine which needed unreserved teamwork to keep it going. To play its part, Mr. Bridge suggested that for shift maintenance it was elementary but essential that the maintenance department should be organised so that the various sections (mechanical, electrical and services) were covered round the clock. Each section should be under the control of a competent supervisor and with sufficient personnel at hand to cope with the normal maintenance required. "Each man should know what his job is and also his place in the team. He must not be left to kick his heels when all is well, but should be delegated to a particular section of plant with a set routine of duty." These men could be marshalled by the supervisor in an emergency, after which they could return to their respective routine duties. Good communications and no interference with the supervisor in charge were necessary for the efficient operation of this method. Day maintenance should be free from routine work on running plant and should be concentrated on periodic overhauls and/or the preparation of spares.

The part to be played by the production department in this teamwork was threefold. First, it could help the maintenance department to keep the plant clean and tidy. "I do not consider it an exaggeration," said Mr. Bridge, "to state that 50% of our maintenance troubles are due to dirt. A clean and tidy plant is usually a trouble-free plant." Second, it could ensure proper training in all plant attendants. Third, it must play its part in close liaison with the maintenance department. For example, prior information of production stoppages (other than for maintenance) enable them to be used for minor adjustments and repairs. The correct and speedy passing of all information, instruction and complaints through the proper channels would do much to build up a team spirit and avoid duplication of effort and confusion of responsibilities.

"To some people," Mr. Bridge concluded, "plant maintenance merely implies upkeep. But good plant maintenance is more than upkeep, it is one of the

answers to increased productivity as, for example, in the shortening of the time required in the relining of a blast furnace or in the re-building of an open-hearth furnace, which can only be achieved through good inter-departmental relations, good teamwork and good planning."

Planned Maintenance

Mr. G. Oram (Appleby-Frodingham Steel Company) then gave a paper on "Preventive Maintenance, Repair Methods, Facilities and Spares." The importance of maintenance had recently been emphasised by high wages for operatives, high cost of services for operation, and restrictions on capital expenditure, which had forced managements to make more use of existing machinery. To be effective, maintenance must be planned and must cover preventive maintenance, routine maintenance and major overhaul.

A comprehensive plant inventory, which should be developed into a plant ledger, was essential before maintenance could be properly planned. The plant ledger should give a concise description of the part of the plant, its costs and an approximate estimate of its life, for appropriate provision in an annual budget for its maintenance. Next, record cards should make it possible to check the frequency of renewals and compare them with the normal expectation of life.

Prevention of breakdowns necessitated "a well organised programme of inspection, so that we have the man with a spanner to tighten the loose nuts, the man with a hammer to knock in the loose key, and the man with a grease-gun to check all the lubrication, where automatic lubrication is not fitted." This must be so directed that every man had to perform his useful and definite task each day. This regular programme of inspection should enable measurements for wear or perceptible damage to be taken and a report made generally on the actual state of the plant. Records should be kept of inspection and work subsequently carried out, which would provide the engineer with invaluable information on the effectiveness of his maintenance plan.

Detailed inspections, at longer intervals than visual inspections, must be carried out at arranged "down-times" to check carefully for actual wear and any perceptible signs of possible failure. Any work requiring immediate attention and which could be done without further interruption should be undertaken right away, if it would extend the time before a major repair.

Mr. Oram claimed that although preventive maintenance required good records, it did not inevitably demand large staff to maintain them. He went on to say that effective preventive and routine maintenance prolonged the periods between general overhauls. When they did become necessary, the management was in a better position, by forecasting and planning, to carry out the repair cheaply and expeditiously.

For a preventive maintenance system to succeed, it was necessary to have the support of adequate workshops, organised and managed for maximum efficiency. "At Appleby-Frodingham," said Mr. Oram, "such workshops were established in 1948, with responsibility for the production of the necessary spares and carrying out the work of reconditioning plant, maintaining all locomotives (then 65 in number), all steam cranes (then 31), and wagons, a varied fleet of some 1,600 vehicles. In addition, they had to maintain their own plant, which was equivalent to an engineering works of reasonable size."

The provision of efficient workshops would not fill the need for certain proprietary and specialised spares. There were various ways in which control could be exercised to cut down the capital locked up in spares; such as standardisation and simplification, and modifications in design to make possible bulk manufacture, while reducing the multiplicity of spares having to be carried. In the average steelworks the value of spares was such as to justify the appointment of a fairly responsible person who might be known as the stocks or spares controller, and he, in turn, should have sufficient staff to maintain accurate records and keep the spares in safe custody in a proper state of preservation. The plant engineer should work in close collaboration with this person.

Manning Problems

Mr. J. Wadsworth (Park Gate Iron and Steel Co., Ltd.), a member of the Productivity Team, gave a paper on "Engineering Maintenance—Manning Problems." He pointed out that within the iron and steel industry of this country, approximately 30% of the total employees were engaged on maintenance, and their wages represented about 40% of the total maintenance costs. He suggested that engineers should pay more attention to the manning problem, as much could be done towards improving efficiency and reducing costs if the right people were available to organise, to supervise and to execute the maintenance work. "Even to-day," he said, "few engineers have a picture which shows the staffing position as it ought to be in 10 or 20 years' time within their maintenance departments."

In organisation, the difficult choice between recruiting managers for steelworks maintenance from electrical or mechanical fitters with technical education on the one hand, or from university graduates on the other might be solved by "a competitive blend." Management skills, in any case, had to be taught and Mr. Wadsworth thought that there was often insufficient collaboration between the cost office and the engineers' department.

The importance of supervision was increased by the fact that few maintenance workers could be paid by individual results. Practice in the U.K. varied, but probably averaged one supervisor to 20 or 30 men; in the U.S.A. there was one for every 10 or 15 men.

Selection and training of supervisors were matters of great importance. The qualities needed in a supervisor were difficult to measure, but merit rating of employees could help. The recording at regular intervals of carefully sought opinions was a useful way of assisting in the final choice for promotion.

Frequently a new foreman had to learn by making mistakes; his introduction to the job was too short, he was given no comprehensive guide to the many complicated procedures or to the extent of his responsibilities. Effective delegation of responsibility was another difficult and related question. Frustration was one of the greatest evils in the lower ranks of managements.

Turning to the problems of workpeople, Mr. Wadsworth suggested that "the aim should be to have a recruitment plan in each works budgeting 10 years ahead in order to provide its own craftsmen, trainee draughtsmen, junior supervisors and engineers." He thought that engineers and foremen should help draft

and operate schemes for selection, workshop training and technical education of apprentices.

In present circumstances it was necessary to keep a high standard of maintenance on a low labour budget. Could job evaluation help achieve this aim? Work study, if engineers gained the confidence of the unions, could be useful. This implied higher standards of joint consultation to aid co-operation at shop level. Better co-operation within each department and between departments would lead to greater efficiency, and everything possible must be done to improve the internal information and consultation services within the maintenance groups.

In an American company—not a steelworks—it had been reported that the use of trained time-study men established a net effectiveness of only 65% of workmen's time, and showed the lost effectiveness was mainly due to managerial causes rather than to any unwillingness on the part of the maintenance workers.

Discussion

The points which excited most discussion were concerned with the organisation of preventive maintenance. Many speakers emphasised that it was not a new conception. One speaker even related it to the Middle Ages, when a knight's squire might make a mental note to have the smith replace a worn shoe "next Thursday." Opinion was divided on whether plant inspectors should come under the plant engineer, or should, as Mr. Oram had described, act as an independent service to the maintenance department.

On the one side it was stated that "it was the plant engineer's responsibility to keep his plant in order, and he did not want to be messed about by a number of people who did not know what they were talking about." Moreover, the routine duties of shift maintenance men were largely concerned with inspection. The normal concentration of maintenance at the weekend made it necessary to employ a larger labour force than could be otherwise absorbed when their services were not needed.

On the other side, it was maintained that fitters not actually engaged on maintenance could be more profitably engaged than in inspection. If the plant maintenance scheme was to run efficiently, the inspectors must be wholly unbiased. In one plant, for example, the inspection department, together with the layout engineers who planned the job after the inspectors had found the need for it, were directly under the chief engineer and in no way responsible to the maintenance engineers. This worked very well indeed, and covered not only the mills and forging plant but all buildings, roofs, roof-lights and so on, all of which came under regular routine inspection. To eliminate the danger of delay, this firm ensured that if an inspector discovered anything which he thought should be urgently dealt with he by-passed the whole system and reported direct to the plant engineer first, afterwards going through the prescribed routine. Delays at this works had dropped from 4·41% to 1·41% in the last six years.

It was also suggested that in many plants a halfway house between the two schools of thought might be appropriate. In these, "resident" maintenance personnel, mainly fitters and electricians were in certain important departments responsible for the continuous operation of the plant, and should do their own inspection. Such items as cranes and locomotives might be inspected by some central organisation.

Problems peculiar to smaller firms were discussed by a number of speakers. It was pointed out that specialised staffs, however desirable, were economically impossible in small firms and often inspection and maintenance were synonymous and simultaneous. One speaker who remarked that he was in the happy position of running both the engineering side and the production side of a comparatively small works which operated a planned maintenance system, drew the moral that they had to select and pay for good people. They could not afford the second-rate. Another speaker, however, from a similar firm reported excellent results from having maintenance inspection normally carried out by the people who did the job ultimately.

Some contributors to the discussion expressed anxiety that compilation of the records and statistics mentioned by Mr. Oram might call for large clerical staffs. Mr. Oram claimed that it was the people who did the jobs who filled in the forms. All the work of looking after the records was in his own case done by two people, a man and a girl. Even in smaller firms there was no reason why it should not be done if it were properly organised. Instead of one man doing one job he might have to do half a dozen, but that did not matter so long as he had the time to do them. Another speaker said that at his works there had been some trouble when they started their scheme because people did not like paper work. But those who had opposed it in the early stages came to realise that planned maintenance was not a matter of displacing the maintenance engineer, but of making his job easier, and that was what in fact it had done.

Another speaker from the same works described how planned maintenance had improved organisation of work during stop weeks. Now they were able to plan everything beforehand and they knew what every man, from the labourers upwards, was going to do. They would not start the job, for example, until they were satisfied that all the spares were ready.

Another speaker, however, thought that paper schemes introduced a danger of losing those personal contacts which were essential to good teamwork.

Mr. Bridge referred to the "considerable improvements" his company had made in relining blast furnaces, simply by the plant engineer and his foreman, in combination with the production department. They all worked together and they paid an incentive to the men. They had a programme which was set out in summarised form and they did the job without layout engineers or outside inspectors.

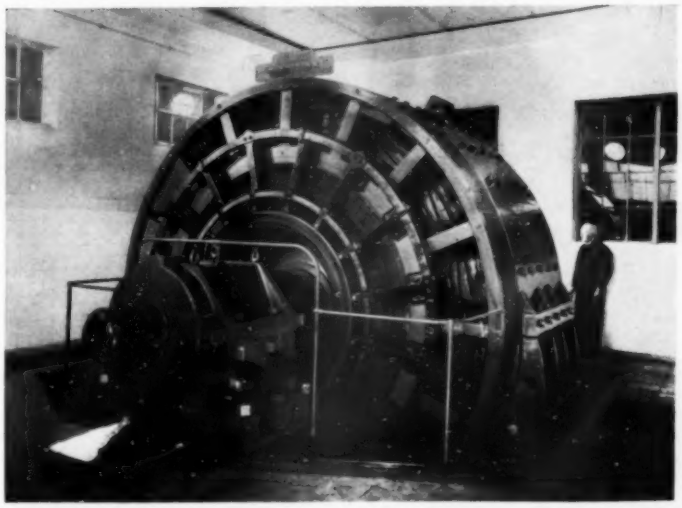
The question of incentive payments was touched on by other speakers as well. One speaker said that his comparatively small firm had operated for five or six years quite a good system of bonus payments on day work for the whole of the engineering department, based on skilled man-hours placed against piece-work earnings of the production department.

For example, the time taken to change a 30 in. × 60 in. 2-high rolling mill had been reduced from eight hours at the weekend to about 2½ hours during the week. This had been achieved by careful planning and by the bonus scheme.

Other points taken up during the discussion included the advantages and drawbacks of time and motion study, in which connection one speaker described a system of walking time-keepers which had saved five men's wages and had been well worth while.

Electrical Plant for the Metal Industries
Progress in 1952 Reported

FOR many years now, the electrical industry has played a major part in the provision of equipment for the metallurgical and metal-using industries. Electrical drives for rolling mills—whether as new construction or for the modernisation of existing mills—undoubtedly constitute one of the outstanding applications of electricity in this field, but a considerable volume of business concerns the smaller motors, switchgear, and, more recently, electronic control equipment. Some idea of the extent to which metal working depends on electricity may be gained from the following information, which has been extracted from the reviews of the activities of a number of the large electrical engineering concerns during 1952.



B.T.H. 4,000 h.p. (12,000 h.p. cut-out) 50/120 r.p.m. D.C. reversing motor driving 37 in. cogging mill at the Round Oak Steelworks, Brierley Hill.

British Thomson-Houston Co. Ltd.

Rolling Mills.

Many important installations of rolling mill drives have recently gone into commission, not only for main drives, but for auxiliary lines of all kinds. An interesting example is the drive put into operation for the new stainless steel sheet mill at the Shepcote Lane Works of Firth-Vickers Stainless Steels Ltd., Sheffield. This mill has two reversing stands: (1) a roughing stand driven by a 2,800 h.p. 30/60 r.p.m. D.C. reversing motor, and (2) a finishing stand driven by a 2,800 h.p. 65/130 r.p.m. D.C. reversing motor. The stands operate alternately, the reversing motor being supplied from a single flywheel motor-generator set, with large contactors for switching each of the motors alternately on to the D.C. generators. The total horsepower of the two mills, edger, screw-downs, edger traverse, slab pusher and coiler exceeds 6,000. The main panel is 125 ft. long and the heavy-current changeover panel is 10 ft. long.

At Round Oak Steel Works, Brierley Hill, the erection has been completed of the second of three reversing mill drives. This is the section mill drive and replaces a steam engine. The reversing D.C. motor is rated 4,000 h.p. 72/180 r.p.m. with a cut-out rating of 12,000 h.p. It is supplied from a flywheel motor-generator set. Another rolling mill installation is the 500 h.p. single-stand cold strip mill drive for the South Wales Aluminium Co. Ltd. It comprises a 500 h.p. 550/1,100 r.p.m. D.C. mill motor and a 60 h.p. winding reel motor, both supplied from a synchronous motor-generator set. There is also a 60 h.p. motor operating as a drag generator on the feed reel. Constant strip tension is provided on both sides of the mill by means of amplidyne control.

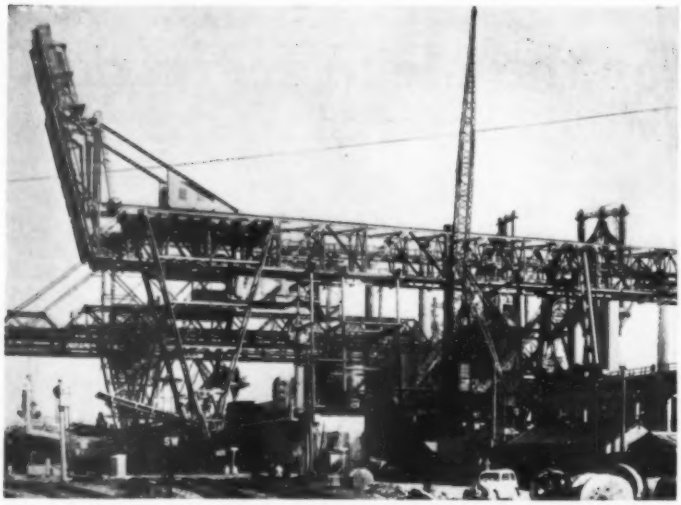
Among new orders received are those for two 300 h.p. 300/600 r.p.m. D.C. motors with grid-controlled mercury arc rectifiers as part of the modifications to a bar mill at the works of Steel, Peech and Tozer, Sheffield. The equipment for a large tube mill includes two 3,000 h.p. 500 r.p.m. 1,100 volt synchronous motors and two 2,200 h.p. 55/115 r.p.m. D.C. motors, the latter being supplied from a synchronous motor-generator set.

Two 1,800 ft./min. coil preparation lines were put into service at the Trostre Works of the Steel Company of Wales during the year. The electrical equipment for each line includes motors totalling 300 h.p. together with their associated motor-generator sets and regulating amplidyne sets, control gear, and photo-electric thyratron loop control. Motors and control equipment for nine hot-dip tinning lines were also despatched to this modern tinplate works for which B.T.H. has supplied a large quantity of electrical equipment including ten sets of 200 kW. 415 volt Pyrobar cast-in heaters for heating the tin pots of the hot dip tinning machines.

A continuous strip annealing and decarburising line has just been commissioned, which includes amplidyne-controlled uncoiler and reel motors, roller-hearth driving motors, and contactor-operated electric heaters with automatic temperature control, and a further order received from the United Steel Companies in connection with modifications to a bar mill, was for a roller table drive incorporating thirty-seven table motors together with associated control gear.

Ore Excavation, Treatment and Handling Plant.

Orders have been received from Ransomes and Rapier for the Appleby-Frodingham Steel Company, covering the complete electrical equipment for two large walking draglines. One of these will be a Type W1400, essentially a duplicate of the one recently supplied to Stewarts and Lloyds for their Corby Works. The second machine, a Type W600, will be approximately half the size of the Type W1400. On the ore treatment side, important extensions planned for the sinter plant of the United Steel Companies have resulted in an order for a con-



This ore bridge at the Margam Works of the Steel Company of Wales was constructed by Ashmore, Benson, Pease & Co., Ltd., and fitted with B.T.H. electrical equipment.

siderable quantity of machines and control equipment, including two motor-generator sets driven by 205 h.p. "No-Lag" motors. For handling iron ore on receipt at the works, a second 12½-ton ore bridge has been commissioned at the Margam Works of the Steel Company of Wales.

Electronics.

Not only has the factory output of electronic equipment in 1952 been a record one, but developments in commercial equipment have been very considerable.

Welding Control.—Among the many developments during the year is that of a novel type spot/seam welding control. In this equipment, the conventional resistance-capacity timing circuit is replaced by two "Dekatron" scale-of-ten counting tubes. In the spot welder these tubes count directly the number of cycles of power delivered to the welder; for the seam welder the cycles "on" and the cycles "off" are counted. The timing is set definitely and positively by switching in the selected cathode of the "Dekatron"; thus troubles associated with drift of calibration of the weld-timing control due to supply voltage variations, temperature, or other factors, are eliminated. The "Dekatron" tubes give a visible indication of the number of cycles counted so that a check on the timing is readily obtained.

Photo-Electric Equipment.—The demand for P–E equipments has increased considerably and developments have taken place in scanning heads, standard P–E relays, register control, sidelay control and pinhole detectors. In one case, the equipment detects a pinhole 0·010 in. dia. in a steel sheet 48 in. wide, travelling at a speed of 1,000 ft./min.

Shear and twist pipe control installed in a rod mill comprises two P–E relays, controlling four modified "Emotrol" panels which incorporate an electronic timing circuit. The equipment is operating satisfactorily despite severe local conditions.

Electronic Motor Control.—Emotrol units have been adapted for special applications of tension control and reeling. One interesting installation completed during the year is for automatic control of tension in metal strip passing through a furnace. Repeat orders have been received from the Royal Mint Refinery for wire-reeling controls.

H.F. Induction Heaters.—The standard range of high frequency induction heaters has now been extended to 25 kW., and several standard heaters have been modified for special applications; one such application required 10 kW./800 kVA. at any one of four work stations selected by manual switching. Elaborate screening and interlocking were necessary on the H.F. busbar layout; the arrangement proved very successful in service.

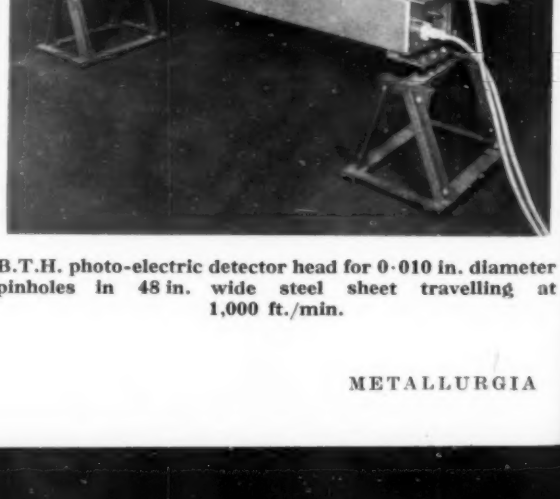
Compressors and Gas Exhausters.

A 3,720,000 cu. ft./hr. turbine-driven blast furnace blower on order by the Workington Iron and Steel Company, will have backward inclined vaned impellors and a partial spiral diffuser system (Oerlikon Patents) giving an adiabatic efficiency considerably better than that of a machine of more conventional design. On the coke-oven side, further orders from the Woodall Duckham Company are for an 800,000 cu. ft./hr. turbine-driven gas exhauster for Richard Thomas and Baldwins; and for two 567,000 cu. ft./hr. turbine-driven exhausters for Guest, Keen and Baldwins. In both cases the machines will form extensions to B.T.H. installations.

Miscellaneous.

Arc Furnaces.—Orders have been received for twelve amplidyne electrode regulators for arc furnaces, while ten such equipments have been despatched from the works. One of the orders received in 1952 was for an equipment for a 60-ton furnace, the largest of its kind to be built in Great Britain. A further design of control cubicle will be standardised in the near future.

Communication System.—The use of the Clearcall system of sound amplification is rapidly growing and the installations completed during the year include communication systems for a hot rolling mill at the



B.T.H. photo-electric detector head for 0·010 in. diameter pinholes in 48 in. wide steel sheet travelling at 1,000 ft./min.

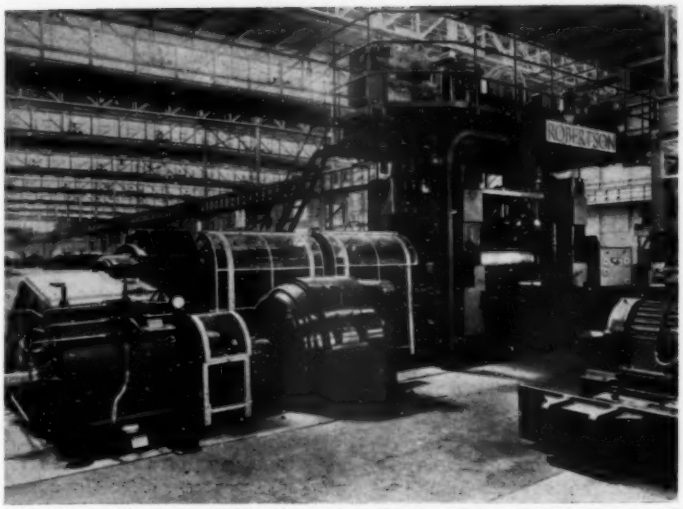
works of the South Wales Aluminium Co., Ltd., for a cogging mill at Steel, Peech and Tozer's works, and for a hot rolling mill at the Aluminium Wire and Cable Co., Ltd. In addition, several export orders have been received, including two for Malaya for use on tin dredgers. Experiments are now being carried out on the application of the method to communication between the ground and moving cranes, and successful demonstrations have been given.

Diesel Electric Locomotives.—Activity has continued in the diesel-electric field and orders have been received for two 275 h.p. and two 400 h.p. sets for the Yorkshire Engine Company's steelworks shunters.

The General Electric Co. Ltd.

Rolling Mills.

Among the rolling mill installations commissioned during 1952 were the two 2-stand temper mills at the Trostre Tinplate Works of the Steel Company of Wales. Each stand is driven by a 1,000 h.p. motor which, together with the driving motors of the tension rolls are supplied from a 2,000 kW. motor-generator set. A second motor generator supplies power for the 300 h.p. uncoiler and reeler motors. Cascade exciters are used to preserve correct tension in the strip, and electronic amplifiers, in conjunction with cascade exciters, provide accurate control of the speeds of the stand motor and the uncoiler and reeler motors.



The sheet skin pass mill in the Abbey Works of the Steel Company of Wales, showing the G.E.C. 400 h.p. 0/500/1,000 r.p.m. mill motor in the foreground.

At the Abbey Works of this Company, the coil skin pass mill and sheet skin pass mill are now in operation, the former being driven by a 700 h.p., 500/1,000 r.p.m. motor and the latter by a 400 h.p., 0/500/1,000 r.p.m. motor supplied from a 330 kW. grid-controlled rectifier. The two strip mills at the Kynoch Works of Imperial Chemical Industries are also in commission, all the electrical equipment, including main and auxiliary drives, being supplied by the G.E.C.

Contracts received include one from the Loewy Engineering Co. Ltd. for the complete electrical equipment for a brass rolling mill, for the Ministry of Supply. For the Australian Iron and Steel Company, Port Kembla, N.S.W., equipment is on order for finishing mill auxiliaries, including coiler, run-out table and loop lifter drives. The contract includes two 7-machine motor-generator sets, two motors for mandrel drives and the associated contactor switchgear and control desks.

Mercury-arc Rectifiers.

The grid-controlled rectifier has been applied to the drive of blowers, rolling mills, draw benches, printing presses, etc. An interesting example is provided by the 2,200 h.p. D.C. motors, driving the turbo-blowers at the Park Gate Iron and Steel Co., which are supplied from a 1,740 kW. twin-cylinder, grid-controlled rectifier. Once the blowers have been put into operation control is entirely automatic. Another example of grid-controlled rectifiers commissioned this year is the sheet skin pass mill at Abbey Works.

Orders in hand for the steel industry include a 1,100 kW. equipment for Arthur Lee and Sons, Ltd., for their Meadow Hall Works, Sheffield. Ultimately this will be the largest rectifier installation supplied by the G.E.C. It was at this steelworks that two 1,000 kW. mobile rectifier sub-stations successfully maintained supplies for nearly a year during repairs to the power plant. Other orders from steelworks include a 200 kW. equipment for the Whitehead Iron and Steel Co. Ltd., a 100 kW. equipment for Ambrose Shardlow and two rectifiers, 250 kW. and 500 kW. respectively, for Tube Investments, Ltd.

Ore Treatment and Materials Handling Plant.

During the year, the chrome ore treatment plant supplied to Sierra Leone Chrome Mines, Ltd., began operation. The ore treated consists of chromite which occurs as small crystals disseminated throughout a siliceous matrix. The plant is designed to produce concentrates required both for metallurgical purposes and for use as refractories. The crushing section handles 150 tons of ore in 8 hours and the concentrating section some 100 tons in 24 hours. The total installed motor power is 220 h.p.; water consumption is approximately 360 gallons a minute, much of which can be recovered.

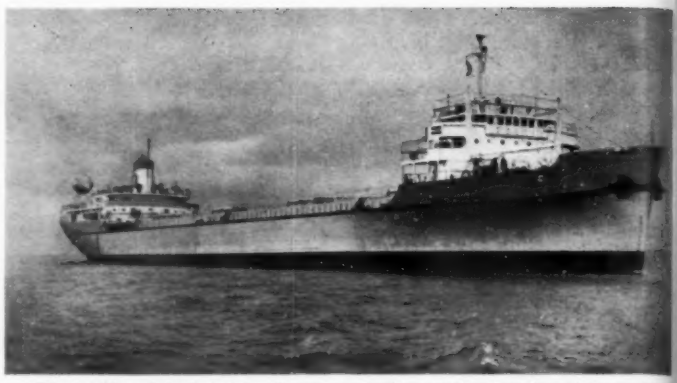
A heavy media separation plant has been designed at the Erith Works for West Africa to treat 100 tons an hour of manganese ore of minus $\frac{1}{4}$ in. plus 28 mesh received from the log washer of an existing installation. The ore contains some 60% of manganese ore and separation will take place at 2·73 specific gravity. A 14 ft. dia. separation cone is used having rotating rake arms. A further such cone is used for dumping purposes. The heavy medium employed will be ferro-silicon, containing 15% silicon, ground down to 98% minus 65 mesh. Three special Sherwen screens are used for draining the sink product and three similar screens for the waste product.

Forty years ago the Erith Works provided the Royal School of Mines with metallurgical and mineral dressing equipment for the then newly built Bessemer Laboratory. During the past year this laboratory has been considerably modernised and one complete room has been devoted to the dry crushing of ores. The renovation of the machines and the provision of new plant was undertaken in collaboration with the School authorities. When the Dry Crushing Room is in full

operation it will be one of the most modern plants of its kind.

As part of the large-scale plant extensions, a complete coal blending and handling plant has been supplied to the order of Simon-Carves Ltd. for the steel works of John Summers and Sons Ltd., at Shotton, whilst for the Kapitalna Iron Works, Zenica, Yugoslavia, a comprehensive contract has been received for a complete ore handling, crushing and screening plant. The value of the latter order, which was placed by Invest-Import of Belgrade, is in excess of £1,000,000.

Of more than usual interest is the equipment supplied for a self-unloading bauxite ore carrier, the *Carl Schmedeman* built by Vickers-Armstrongs, Ltd., Barrow, for Reynolds Jamaica Mines, Ltd. The handling plant comprises two hold conveyors taking the gravity discharge from inbuilt hoppers and discharging on to a shuttle conveyor which, in turn, discharges at either side of the ship.



The self-unloading bauxite ore carrier, "Carl Schmedeman."

Turbo Blowers and Generators.

Turbine driven blowers are on order for blast furnaces at the Redcar Iron Works of Dorman Long and Co. Ltd., for Bairds and Scottish Steel and for Colvilles Ltd. Two turbo-type blowers are in operation at the Park Gate Iron and Steel Co. Ltd., Rotherham, each driven through gearing by D.C. motors; speed control to secure maximum efficiency at all loads is by means of grid-controlled rectifiers with additional anodes for supplying the motor fields. In the power house of the Steel Company of Wales at Margam Works, three turbo-type blowers, two turbo-alternators and one double pass out back pressure turbo-alternator are now in commission.

The Norwegian State Power Company has placed a contract for a 50 MW, 12·3 kV., 428·6 r.p.m. horizontal shaft alternator for Pelton wheel drive for use in the new aluminium plant at Sunndalsora; it will be one of the largest hydro-electric sets of this type in Europe. The alternator will weigh over 310 tons and is specially designed to enable it to be shipped in sections. Several smaller hydro-sets are on order for this Company.

Miscellaneous.

Electro-magnets.—Lifting and separator magnets are being built for service at home and for export to Canada, Northern Rhodesia, U.S.A. and Sweden. They include special water-cooled magnets for charging billets into rotary hearth furnaces; such a magnet has recently been put into service at Tubes, Ltd.

Photo-Electric Devices.—A further development of the photo-electric press guard permits sheet metal to be inserted into the press without interrupting operation, but if the operator's hand follows the sheet, the press is immediately shut down.

Photo-cells are also used in the control of the flying crop shear of the 80 in. continuous hot strip mill at the Abbey Works of the Steel Company of Wales. Operation is initiated by light from the hot metal striking the photo-cell.

(To be continued.)

Change of Telephone Number

We are advised by Foundry Services, Ltd., Birmingham, that, due to an increase in the number of their telephone lines to ten, their telephone number has been changed to East 1911.

McKechnie "Twenty-Five" Club

The inaugural meeting of McKechnie Brothers Birmingham Works "25 Club" took place at the White Horse Hotel, Congreve Street, Birmingham on Friday, January 9th, 1953. The First President, Mr. John Rae, a Director of the Company who joined the firm over 54 years ago, received the members and guests, and later made the presentations of watches or clocks to the 17 employees who celebrate their 25 years with the Company and who become members of the club, which now has a membership of 188. Mr. H. Hollingworth, the First Vice President of the Club, with 43 years service, assisted the President.

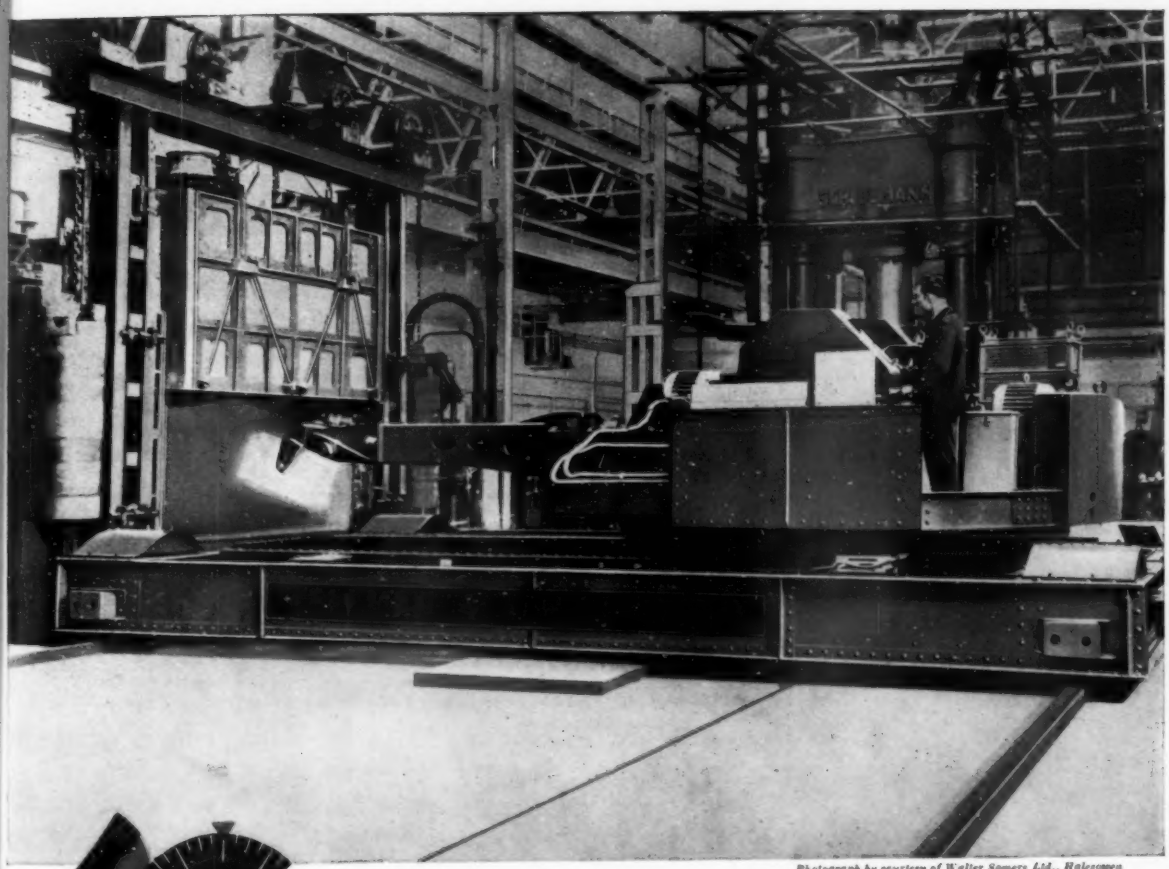
Apart from the presentation to the new members, the object of this gathering was to enable old employees to get together and reminisce to their hearts content, aided by a little judicious entertainment. Whilst this is the first meeting of the Birmingham "25 Club." the Widnes Works of the Company have had their "25 Club" since 1949.

Nickel Price

The Mond Nickel Company, Limited, announces that, following the announcement in Canada by The International Nickel Company of Canada Limited, of an increase in the price of nickel effective January 14th, it is, as from the same date, raising its price for refined nickel in the U.K. to £483 per ton, delivered works, with appropriate increases for other countries.

Representation in Japan

New Metals and Chemicals Ltd., of 16, Northumberland Avenue, London, W.C.2, announce that they have appointed Messrs. New Metals and Chemicals Corporation, of Mihara Building, 5 Ginza Higashi 4 Chome, Chuo-ku, Tokyo, as their representatives for Japan. The Japanese business is under the management of Mr. J. Barth, who took up residence in Japan in 1921 and is well known in metallurgical and chemical trade circles there.



Photograph by courtesy of Walter Somers Ltd., Halesowen

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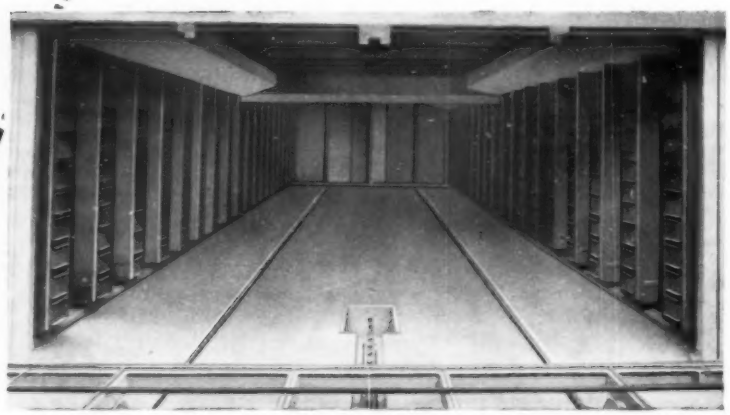
Air Circulating Ovens

Illustrated is an ageing oven, supplied to a prominent aircraft manufacturing concern, to take up to 24 feet long light alloy sections. The sections are truck-loaded into the oven, the truck running on rails. A centre door, half-way along the chamber, enables the oven to be split into two 12 foot sections, each section having independent temperature control, thus saving electricity costs by using only half the capacity of the unit. Each half of the oven is provided with its own external heater battery and large volume circulating fan.
From the view of the chamber will be seen the series of heater ducts mounted on each side wall. The fans are of the centrifugal type with the impellor shaft mounted in ring oiled bearings, the inner bearing being watercooled. The total rating is 150 kW. Two sets of switchgear and oil circuit breakers are mounted on the outside wall of the oven casing. Each section of the unit is equipped with its own independent dial-type indicating controller.



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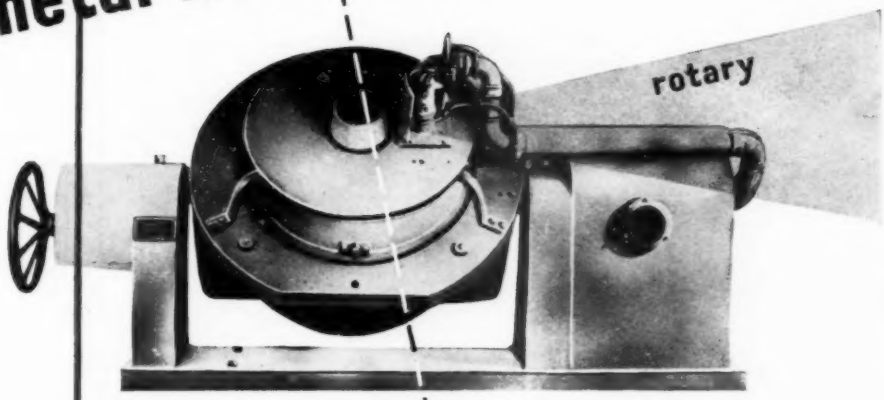

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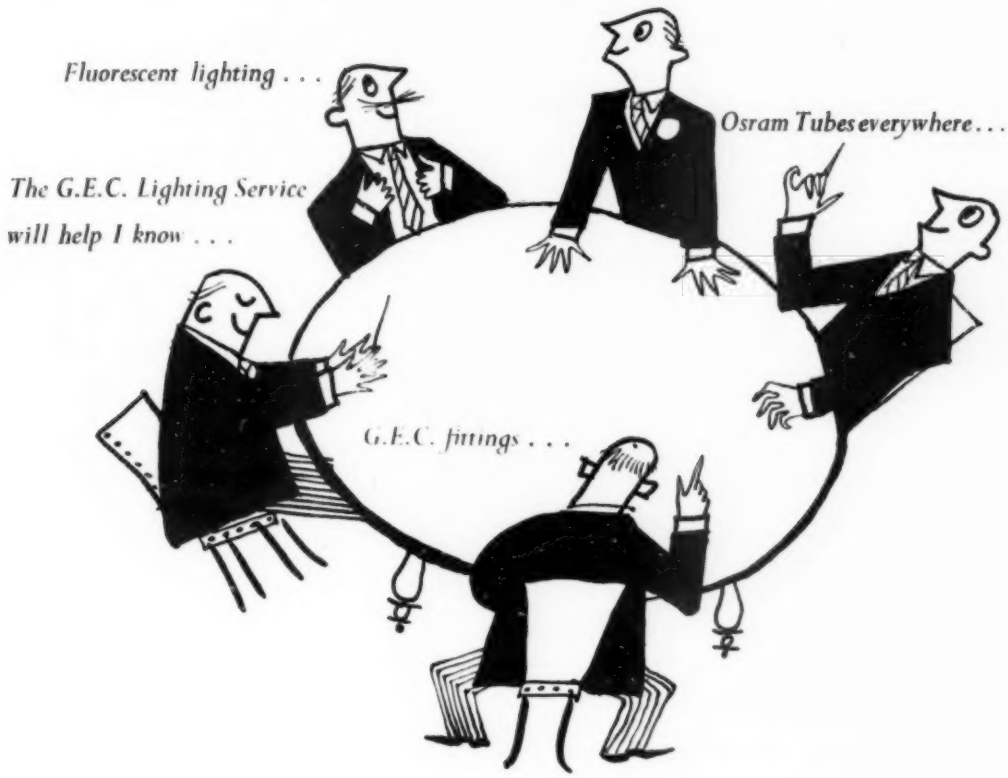

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Aluminium Development in Relation to Supply

By E. G. West, Ph.D., B.Sc., F.I.M.
Technical Director, The Aluminium Development Association

Aluminium is the most abundant metal in the earth's crust, and while much of it is in a form unsuitable for economic extraction, there is no doubt that this material is playing an increasingly important part in the material progress of mankind. After outlining the plans made to ensure economic supplies, the author deduces probable future trends from a study of the pattern of development over the last fifty years.

THE importance of aluminium supplies was highlighted by Professor Murphy[1] in his recent broadcast in the Science Survey series, during which he showed clearly the major contribution which aluminium will make to the world total of metal available to mankind. He was looking forward particularly to the next generation or so, and there is no doubt that to-day the aluminium industry stands at the very threshold of its adult life.

Its period of infancy can be said to cover about 60 years, from its isolation in 1825 to the discovery of the modern electrolytic process of reduction in 1886, when world production was some 16 tons per annum. Adolescence has been the usual mixture of youthful enthusiasm and doubtful starts, followed subsequently by rapid growth and expanding interests until world production to-day stands at nearly 2 million tons per annum. Even at this level, which exceeds the war-time peak, there has been a shortage of aluminium throughout the world, and it has been impossible to continue many new applications, still less embark on new developments. Plans have, therefore, been laid—and some are already being implemented—to increase world output by many hundreds of thousands of tons; in fact, it is hoped to double the available metal in the next 10 to 15 years. This indeed is a good start for the ever-increasing rôle which aluminium is destined to play in all the great industries of the world.

The future of aluminium is undoubtedly bright, whether the long term or the immediate short term is considered. Metal producers, secondary metal smelters, fabricators and makers of semi-finished products, manufacturers of consumer goods and ultimate users all stand to benefit from the position in which the metal stands to-day. All sections of the community will benefit from the intensive scientific research undertaken since the aluminium industry was first established, from the basic investigations promoted with the intention of opening up new fields of application, and from the expansionist policy followed by the leaders of the industry since its early days. Market development is inextricably bound up with, and largely governed by, scientific and technological advances in many fields, and equally with the availability of adequate supplies of metal at an economic cost, but no one of these factors is more important than another. They are all interdependent, and it is the purpose of this article to outline first the plans made to ensure economic supplies and then to show how the pattern of development since the early days of the industry indicates the probable future design which the industry will weave.

1 A. J. Murphy. "Science Survey" Broadcast—"Metals To-day and Tomorrow," 8th January, 1953.

The Future of Aluminium Supplies

It must be recalled that the aluminium industry is an international industry in which many nations, many lands, and many ideas are closely concerted. There is a greater abundance of aluminium in the earth's crust than of any other metal, but the way to win it still involves the expenditure of enormous quantities of electric power—over 18 million kilowatt hours per ton of metal—and unless some fundamentally new process is discovered there seems little hope of substantially reducing this power consumption. It is this factor which has led to the present distribution of smelting capacity, and the distribution is only likely to change substantially and fundamentally if, and when, atomic energy becomes comparable in cost with water power.

It is well-known that the economic production of virgin aluminium in the United Kingdom has been relatively static at approximately 30,000 tons per annum, and there is no immediate prospect of this total being increased. Before 1939, production in Scotland was a substantial proportion of the United Kingdom's requirements, an approximately equal amount being imported from Canada, and about half as much from European countries. Great Britain's present requirements of virgin metal have increased to some 200,000 tons to which must be added the 80,000 tons obtained from the refining of scrap.

This recovery of metal from broken and obsolescent equipment represents a substantial and major change in the make up of the industry in the last 13 or 14 years, and scrap is beginning to play almost as important a part in the aluminium industry as in the steel and other older metal industries. Thus, it is reasonable to expect refining to become even more important as the metal which went into consumer goods 20 to 25 years ago begins to return as scrap. It is, therefore, advantageous to the industry that control of the grading, re-melting and refining of scrap has already reached a well-defined position, which should militate against the wrong use of scrap material.

Raw Materials

Bauxite remains the only ore used for the commercial production of aluminium, although it is confidently forecast that should a war demand arise again it might well be feasible to extract metal from clay. Much basic work has been completed on the processes involved, and although they are not economic under normal

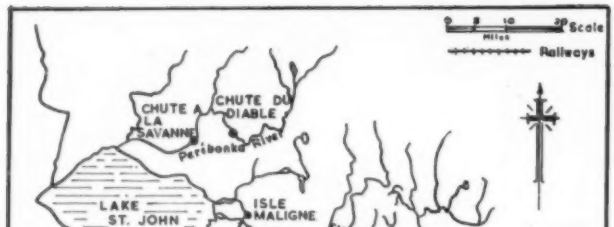


Fig. 1.—Sketch map showing location of hydro-electric schemes and aluminium reduction works in the Saguenay area of Quebec.

conditions, strategic demands may well bring them into large scale production. Bauxite is mined in all quarters of the globe, and the more important deposits at present worked are in the British and Dutch Guianas, the East and West Indies, the United States of America, the U.S.S.R., Italy, Jugoslavia and Greece, whilst more recently the deposits of West and East Africa, of Brazil, of Australia and of India have been opened up. Bauxite is, of course, the source of other important industrial products such as abrasives, refractories and aluminous cements, and a large proportion of the bauxite mined does not end up as aluminium.

Before the war, world production of bauxite was less than 4 million tons per annum, but during the war it reached a peak of over 14 million tons, falling again at the end of the war to the pre-war figure. By 1948 the total had doubled, and during 1951 more than 10 million tons of bauxite were produced, almost one third from Europe and most of the remainder from North and South America. Extensive development of bauxite resources is taking place, and two sites are of particular interest to the British Commonwealth, namely, the Gold Coast of West Africa, from which a certain amount of bauxite has already been shipped to Britain and Canada, and Jamaica, where a new subsidiary of Aluminium Limited (Alumina Jamaica Limited) has started extensive and far-sighted operations. It is of interest to note that the Canadian objective in Jamaica is to convert the bauxite to alumina before shipping it to the new smelters in Western Canada. This development of the Jamaican bauxite industry is linked with rehabilitation of the land from which the ore has been removed by excavation.

The other essential ingredient required for the production of virgin aluminium is cryolite, which has been obtained almost exclusively in the past from the natural deposits in Greenland. These are becoming worked out and, in any case, were inaccessible to some aluminium producers during the war. Considerable research has therefore been undertaken on the economic production of synthetic cryolite, and the problems involved have been successfully solved. This double fluoride is, of course, used as the electrolyte in the reduction process, and commercial production of the synthetic variety is now undertaken on a large scale.

Metal Reduction

Aluminium reduction commenced in Scotland before the end of the last century, when the British Aluminium Company Limited began operating the electrolytic process on bauxite imported from Larne in Ireland. The extensive hydro-electric schemes and their accompanying reduction works at Foyers, Kinlochleven and Lochaber have been fully described[2] and are familiar to many visitors to Scotland.

Canada has become one of the world's greatest producers of aluminium, and the United Kingdom relies on Canada for about 200,000 tons of metal per annum. Reduction of aluminium commenced on the St. Maurice River in 1900, using power from Shawiningan Falls in Quebec Province, and 25 years later new works were undertaken further north in the Saguenay district of Quebec. Here the Peribonka river drains into Lake St. John, and the Saguenay flows from it to the St. Lawrence. The smelters and hydro-electric works are shown in Fig. 1. The principal smelters are situated at Arvida, drawing power from the two mighty dams at Shipshaw. The town of Arvida was created by the aluminium company and more recently a 500 ft. span aluminium bridge has been built there across the Saguenay river. At the Arvida smelter, over one million horse-power of electrical energy is used, derived from a number of separate plants. The power is transformed

2 W. Murray Morrison. Institute of Metals Autumn Lecture 1939, *J. Inst. Met.*, **65** (2), pp. 17–36.

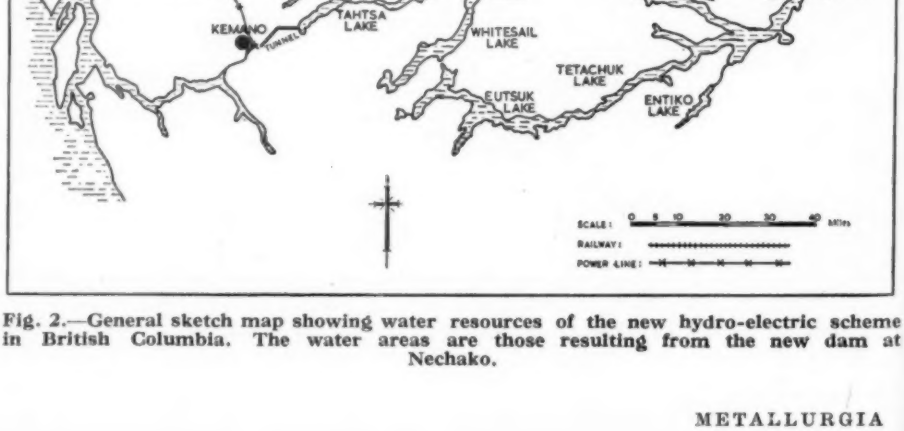


Fig. 2.—General sketch map showing water resources of the new hydro-electric scheme in British Columbia. The water areas are those resulting from the new dam at Nechako.

and rectified before being fed into the 22 pot lines in which aluminium is produced at a lower cost than anywhere else in the world. The works cover over 400 acres and the two principal sources of power at Shipshaw are near-by. The Saguenay river involves a water shed of some 300,000 square miles, Lake St. John itself covering 400 square miles. There are two plants at Shipshaw, No.1 which generates 200,000 horse power and the mighty No. 2, 1,200,000. Shipshaw No. 1 was completed in 1931 but No. 2 was a product of the war when the first two units went into service only 15 months from the beginning of the necessary excavation. Further up the Saguenay river is the second aluminium works at Isle Maligne, where a plant of over half a million horse power supplies a reduction works capable of producing 85,000 tons of aluminium per annum. Some 50 miles from Arvida, there are two other major power schemes nearing completion, both on the Peribonka river. At Chute du Diable, over 250,000 horse power will be generated, and with the neighbouring Chute à la Savane over 400,000 horse power will be available for aluminium reduction at Arvida, the power being conveyed across country by overhead lines.

British Columbia Project

The largest project yet undertaken for the production of more aluminium is in the West in Northern British Columbia, where a new power house is to be built at Kemano to supply a new reduction works at Kitimat. In this mountainous region, seven lakes are being linked and their levels raised to make an entirely new water system which reverses the flow of the rivers from East to West. A dam 300 ft. high by 500 yards long is being built at Nechako, and from the resulting reservoir water will be conveyed through a tunnel 10 miles long to a power station built within the mountain itself. Initially 450,000 horse power is to be installed, but the plan includes an ultimate total of about 2 million horse power. The current is carried some 50 miles over mountains running up to 6,000 ft. to the new plant which is being built together with a new town on the site of the old Indian village of Kitimat. This is on the Douglas Channel, thus allowing ocean-going vessels to unload their alumina and bauxite, and ship metal, adjacent to the works. The plant at Kitimat has been planned for 500,000 tons of aluminium per annum, so that in the future Canadian production will be of the order of one million tons. During 1952 output was some 450,000 tons and an extra 100,000 tons is confidently expected by 1954.

Two important economic factors influence the supply of aluminium from Canada, which uses but a small proportion of its total output. First, Great Britain has invested many millions of pounds in Canada to assist aluminium expansion. During the war some 56 million dollars were loaned, a further 25 million were invested in 1950 and 40 million in 1951, making a total of some 120 million dollars. In return, Canada has contracted to supply the United Kingdom with aluminium up to a total of a quarter of a million tons per annum until 1971, but it must be recalled that the metal still has to be paid for in hard currency. The second factor is the considerable tonnage of aluminium sold annually by Canada to the U.S.A.; this is of the order of 100,000 tons, but American producers are also increasing their smelter capacity, which to-day is about ten times that of 1935.

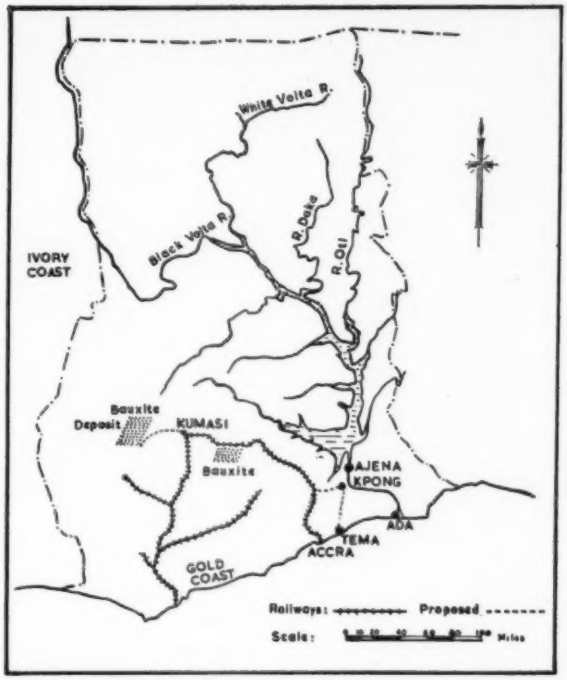


Fig. 3.—Sketch map of the projected scheme on the Volta River. The water area is that resulting from the dam proposed at Ajena.

The importance of new reducing plants in other parts of the Commonwealth must not be overlooked. Australia is now planning to produce annually about 13,000 tons of aluminium ingot at a plant to be located on the River Tamar at Bell Bay in Northern Tasmania, using a mixture of Australian ore and imported bauxite of higher quality. This will make Australia self-sufficient in aluminium for some time to come. There have also been proposals for an aluminium reduction works in the South Island of New Zealand, with a possible annual output of 60,000 tons, and again this would make the country self-sufficient in aluminium. India is also planning to increase its aluminium production which at present is rather less than 10,000 tons per annum against the 1951 consumption of 16,000 tons. It is now proposed that there should be a new smelter on the Hyrakund electricity site to begin production in 1955, bringing the total aluminium output to some 20,000 tons per annum.

Volta River Scheme

The largest project in the sterling area is the Volta river scheme on which a White Paper has recently appeared[3]. Here it is intended that the local bauxite shall be mined, processed to alumina and reduced to aluminium all on the Gold Coast. This fully integrated scheme will use power to be provided by a hydro-electric plant to be built on the Volta river at Ajena. The dam here will create a 200-mile long lake and make available power totalling three-quarter of a million kilowatts. The dam is situated about 70 miles from the mouth of the river and development work will be necessary to provide

3 Volta River Aluminium Scheme, H.M. Stationery Office, Cmd. 8702. 1952.

a suitable port. The general outline is shown in Fig. 3. The power scheme and transport facilities are to be covered by the U.K. and Gold Coast Governments, and 200,000 tons of aluminium per annum would be produced within 20 years. On this basis the bauxite deposits there would last for about a century.

Smelters Outside the Commonwealth

Although this summary is dominated by the position of British Commonwealth smelters, the importance of increasing aluminium production in other parts of the world must not be overlooked. The U.S.A. is planning considerable expansion of its aluminium capacity in spite of the difficulties in obtaining sufficient power from hitherto untapped sources. It has recently been announced that the American proposition to use power in Alaska derived from Canadian rivers has not been accepted by Canada, and this indicates the importance attached to the exploitation of hydro-electric resources for the production of aluminium and other products requiring large and continuous supplies of electricity.

S. America is also becoming an aluminium producer using its own bauxite. For example, Brazil has large reserves and now will operate two smelters, one at Saramenha under Canadian control. This commenced reduction in 1945 and in due course will produce 3,500 tons per annum. The second plant will start up in 1953 and is planned to produce 10,000 tons per annum in 2 or 3 years time, with an eventual capacity of 50,000 tons per annum supplying an integrated fabricating industry.

Reduction of aluminium on the Continent has been undertaken in France, Switzerland, Germany, Italy and, especially, Scandinavia, where water power has been largely responsible for the location of works, although Germany built up its enormous aluminium output of some quarter of a million tons during some of the war years with 40% of its power produced from coal. Some expansion of European smelting capacity is planned; thus Norway with an output of 40,000 tons per annum is now doubling its output and has resumed exporting aluminium ingot to Great Britain. Germany has already increased its output from 7,000 tons in 1948 to almost 100,000 tons in 1952. The cost of aluminium reduction in Germany is some 25% greater than Canadian costs and at present Germany not only fabricates all its ingot production but also imports a small quantity from Canada, German exports being limited to semi-finished forms and manufactured goods.

The U.S.S.R. remains shrouded in secrecy, but careful study of the data published in the latest 5-year plan indicates the intention to increase aluminium production substantially by increasing available power and by increasing the supply of the chemicals required. These indications, coupled with the known reserves of bauxite show that the last estimated figures for virgin aluminium production in Russia are likely to be substantially exceeded within the next few years. Japanese smelters are again in production and planning to increase output.

All these facts show clearly the international character of the aluminium industry and its problems. They indicate also that there is no intention of sitting back and waiting for supplies to increase or markets to expand—the development of new applications is proceeding apace throughout the world.

Development in the United Kingdom

Various estimates have been put forward for future British requirements of aluminium, and one recent assessment, stated to be conservative, indicated that the United Kingdom could use during the ten-year period 1950–1960 an average of 5% more each year. Another forecast says that by 1975, i.e., in a 25-year period, approximately three times as much aluminium would be required as at present. Yet another estimate, attributed to Aluminium Limited, states that world demand foi aluminium may rise as much as fourfold in the next 20 years.

All this pre-supposes that the metal is freely available at competitive prices, and although this last aspect is outside the scope of the present review, it should be noted that the serious increase in price which has taken place during the last three years should not be assumed to indicate the trend that is likely in the future. A recent speech by the Chairman of a major fabricator has pointed out "that in only three years the price has risen from £90 to £166 per ton, with four separate increases in 1952. While this may be largely attributable to the weakening of sterling in relation to the Canadian dollar, the fact remains that in this country the price relationship of aluminium to steel has moved considerably in favour of steel." This recent trend should be compared with the almost horizontal line which was the curve of aluminium prices before the war. There is no doubt that Canada is, at present, the world's lowest cost producer, and there is equally no doubt that as soon as there is surplus virgin aluminium available almost anywhere in the world, the natural process of price regulation by supply and demand will come into play.

In the same way that aluminium requirements of the United Kingdom cannot be separated from world production and prices, so the development of new applications cannot be confined to Britain, and there is already a considerable exchange of ideas between the various fabricating countries at the technical level. The results of development research in Great Britain compare favourably with those abroad, but it has to be admitted that some of the basic work undertaken has unfortunately not always been applied first in this country.

The pattern of future development will continue to be influenced by the pattern of the past. It is, therefore, of interest to look at the general growth of the use of aluminium, noting that some early applications were not always successful owing to lack of knowledge, whereas more recent investigations have shown the way to success.

The earliest uses of aluminium were based on the obvious properties of low weight, resistance to atmospheric attack and high conductivity for heat and electricity. It must not be forgotten that Charles Dickens in one of his earliest writings, in 1856, forecast a most promising future for the then newly available metal, and some of his prophecies are already fact.

Influence of the Aircraft Industry

The invention of the internal combustion engine at about the same time as aluminium was emerging from infancy to adolescence gave a great impetus to both industries. The advantage of low weight, coupled with high heat conductivity and the relative ease with which alloys could be cast into complex forms made aluminium

an easy choice for many components of early motor cars and, later, aircraft. Experience in the aircraft industry with its exacting requirements for strength, consistency, reliability, high dimensional accuracy and ability to undergo severe and varied working operations, laid the foundation and pointed the way to the large-scale general engineering uses which have taken place during the immediate post-war period. Much of the progress made in the development of new alloys and new processes by the aluminium industry has sprung from the demands of the aircraft designer, but the alliance between the two industries has not always been to the the advantage of aluminium. Thus, plant suitable for producing material for aircraft is not always suitable for economically producing metal for less exacting tasks and, furthermore, the high standards of inspection to which the industry became accustomed are unnecessary for many other applications. A process of re-equipment and re-education, therefore, had to be undertaken by the aluminium industry. Not only had the industry to educate itself, it had to undertake the very much larger task of informing and educating the using industries, and, particularly, the potential users, to think in terms of aluminium. Basic research by the industry itself and through the research associations has been followed by development work, partly by individual companies and partly through central organisations. In many spheres standardisation has followed these investigations.

In Table I are shown approximate figures for the end uses of aluminium in the United Kingdom, excluding direct exports which have been an important factor since the end of the war. It will be seen that many markets of to-day have followed directly from the earliest applications.

Early Applications

Aluminium holloware was tried when the sodium reduction process was in use commercially, and the steady growth of aluminium for utensils has continued with every advance in the preparation of food and drink, both on the domestic and commercial scale. Indeed, aluminium was known to many only in the form of pots and pans until the call by Beaverbrook during the war made everyone aware of the importance of aluminium as a high grade engineering material.

Another early application was jewellery, statuary and other decorative features dictated both by its relatively high price of those days and its permanence when exposed to the atmosphere. Aluminium jewellery went out of fashion nearly 50 years ago, but the wheel has come full circle and costume jewellery of high-purity metal, finished by chemical or electrolytic polishing and colour anodising, is now popular on the Continent and here. The tonnage of metal involved is small, but it represents a significant incursion into the traditional heavy metal markets, and the advantage of low weight coupled with ability to resist tarnishing should make this use permanent for aluminium.

TABLE I.—THE PRINCIPAL COMMERCIAL USES OF ALUMINIUM IN 1950 AND 1951.

	1950		1951	
	Tons	% of Total	Tons	% of Total
Direct exports	38,464	16	32,257	12
Road vehicles	48,211	20	48,178	20
Building	35,531	15	22,878	9
Electrical uses	10,698	4½	13,349	5
Packaging	15,808	7	27,989	10
General engineering	13,017	5½	11,170	5
Domestic equipment	13,099	5½	14,193	5
Holloware	8,596	3½	9,732	3½
Chemical and food trades	1,865	1	1,648	½
Marine	2,190	1	1,913	1

Fig. 4.—One of the latest road transport developments—cattle lorry with aluminium framework and flat bottomed floor embodying a total of 1¼ tons of aluminium. Aluminium castings are inserted between the top-hat sections of the ramp and of the floor to prevent slipping.

Electrical conductors were an early application and have developed continuously. Experience with the grid erected around 1930 has been successful, and the supergrid is now to embody steel cored aluminium cables. At the present time, electrical applications are very attractive owing to the relatively higher price of copper, on the basis of both weight and current carrying capacity. Development is taking place on low-tension distribution lines; experimental work is proceeding on various types of flexible cable, and the early work on aluminium busbars is bearing fruit in new commercial interest. Aluminium for cable sheathing instead of lead is rapidly becoming established, and the pioneer company in this development had sold over 2,000 miles before the end of 1952.

Automobile and Building Industries Greatest Users

The automobile industry is the largest user of aluminium, taking some 20% of the total, of which about a half is in the form of castings. Commercial vehicles, both goods and passenger, account for by far the greatest tonnage of aluminium, although its place in motor cars is gradually increasing. Several technical problems have militated against the general adoption of aluminium for cars, but these have been subject to extensive investigation, with the result that there are now few, if any, technical reasons preventing light metal from improving the power/weight ratio of the private car coupled with freedom from rusting of bodywork, doors and wings.

The non-heat-treatable aluminium-magnesium alloys

Courtesy of Barnard and Smith.

Fig. 5.—The Commonwealth House. This prototype is a good example of factory-built aluminium dwellings for export.

are most suitable for body pressings, but may show a tendency to stretcher-strain markings, similar to but not identical with those which have been troublesome in the production of steel car body pressings. Research by the B.N.F.M.R.A. and the aluminium industry has resulted in this disability no longer proving troublesome. The joining of aluminium motor car components has also received attention, and the newer methods of welding and brazing are satisfactory, while making good and filling up the inevitable dents and deficiencies of sheet metal work have been overcome by new methods of applying satisfactory solders and other fillers. But in accepting aluminium for car bodies the motor industry must be assured of ample supplies of suitable sheet at a steady price. There are many other ways in which aluminium may lighten vehicles still further, thus improving efficiency and allowing a greater standard of comfort to the passenger. More use of die-cast components is possible to replace assemblies built up from wrought materials riveted or welded together, and the welding of simple castings to form complex units is worth further development. The engine radiator is one of the heaviest components not yet produced in aluminium, but, backed by the extensive experience of aircraft radiators and intercoolers, the industry should be able to capture another market for its sheet production.

Building constitutes the next largest outlet for aluminium and the experience gained, plus the competitive spirit engendered by the aluminium pre-fabricated bungalow, followed by the efficient factory-built aluminium schools, should assist the industry to enter this field. Recent attention to aluminium roofs cladding for side walls, more efficient windows, aesthetically pleasing and workable fittings and furniture, better heating appliances and other building items show the trend. Interest in building has led to considerable work in structural engineering and again there is a good record of British success. The problems involved in designing efficient aluminium structures, containing the minimum amount of metal, with sufficient rigidity to stand comparison with steel and other structural materials, have been largely solved, with the result that some of the most interesting structures yet designed have been built here, such as the new hangars at London Airport and Hatfield.

Marine and Packaging Applications

Early attempts to use aluminium for marine purposes were not always successful owing to the lack of suitable alloys and the neglect of elementary precautions, but laboratory research and service experience over the last 20 years has established aluminium for big ships and small boats. Work in the early 1930's showed aluminium to be entirely satisfactory for small boats, and it has been increasingly applied to structural items of ocean-going vessels. The new Atlantic record holder, S.S. *United States*, is the most spectacular application of aluminium to date, carrying as it does some 2,000 tons of aluminium in its superstructure and internal fittings. Little has yet been published on this remarkable vessel, but experts feel confident that a still greater use of aluminium could be made on any vessel of comparable size built now in Britain. Other interesting developments now at the commercial stage are structural parts of cargo ships and cargo-passenger liners, hatch covers and bulkheads, special purpose vessels such as bulk ore carriers, and aluminium barges for the great rivers of the world.

It is often stated that packaging ranks as the greatest

Fig. 6.—Fire test carried out by the Aluminium Development Association on a full scale model aluminium cabin as part of the programme of research on applying aluminium to marine structures. The illustration shows the cabin immediately before test with the thermocouples in position. A full report of this and other tests was recently presented to the Institution of Naval Architects.

potential use of aluminium, but it is very largely dependent upon cost. In some types of pack, aluminium is already considered to be the best material, for example, for collapsible tubes except in the smallest sizes where the metal is a major factor in the total production cost. It is well-known by British travellers on the Continent that collapsible tubes could be used to a very much greater extent for many foods not yet packed in this manner, such as condensed milk and cream, sauces, mustard, pastes and numerous similar items. Co-operation between the aluminium industry and the tube-makers, the food manufacturers and packers, and ultimately the retailer and the customer is necessary to take advantage of the opportunity for expansion. Aluminium foil is well established for packaging many foods, and production now exceeds 12,000 tons a year, of which nearly half is used for milk bottle tops. The combination of aluminium foil with other packaging materials to form heat-sealed wraps is increasing, and a considerable tonnage for foil may be sold for use domestically for cooking and for preserving food. This has already made great progress in America and is an immediate possibility for expanding foil sales here. Canning presents difficult problems owing to the many types of food or other product which have to be processed and held without damage to the container or the food for long periods. Much progress has been made, but the ultimate tonnage of aluminium used depends very largely on the cost of metal, for fabricating the pack and its treatment costs about the same in any material.

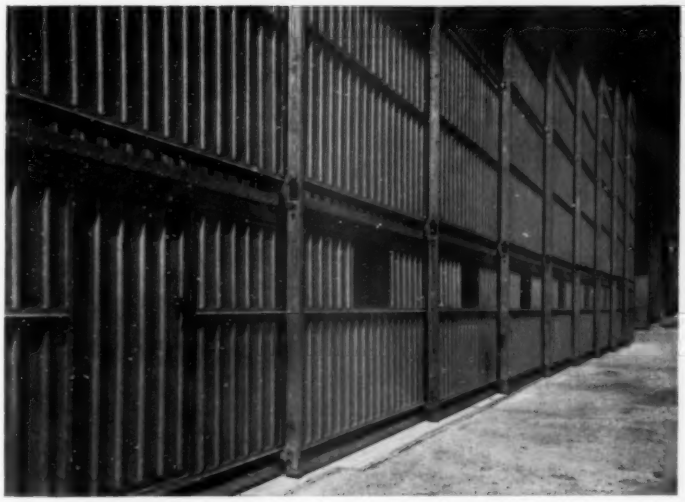
Turning to smaller markets, but still potentially important ones, consideration must be given to railway vehicles, which have hitherto proved somewhat disappointing in this country, although rather more spectacular successes are claimed abroad. Reduction in weight of 50% compared with steel is normally achieved in vehicles and this is a direct saving of power, particularly on suburban electric line services with their frequent acceleration and stopping.

Mining equipment, agricultural equipment and many other general engineering fields, such as printing and textile machinery, all offer potentialities which are being exploited. In some of these applications the higher initial capital cost of aluminium militates against its more ready adoption, though great savings in weight and power can be effected. The use of aluminium equipment in coal mines should assist the labour shortage there and help to achieve the greater production required. The permanence of aluminium compared with many other materials makes it attractive in agricultural and horticultural equipment, in spite of the technical problems and cost factors.

Conclusion

From this brief review it will be seen that the aluminium industry of the world is planning to produce enough metal to satisfy foreseeable needs for the next 10, and probably for the next 20 years, and on this account there should be no reason for potential users to hold back due to fear of metal shortage. The new capacity should result in a fall in price relative to that of competitive materials, and the expenditure already incurred and projected on long-term research and development should show a substantial return in establishing new permanent markets.

The immediate short term position in Britain, whilst still good, is rather less rosy than the long term prospect and there is no doubt that maximum attention must be devoted to securing the early application of the results of the basic investigations completed to date. It now appears that there will be sufficient metal during 1953 to meet all normal needs but the productive and fabricating capacity of the industry will not be fully occupied without major efforts on the part of the industry. One of the most promising immediate outlets likely to benefit the national economy is that of building, where there is ample scope for applying the results of technical investigations and service experience with a certainty of success. Other major developments will not be neglected and the momentum already gained should be multiplied by a substantial factor before the end of the year.



Courtesy of S.M.D.Ltd.

Fig. 7.—Portion of the new aluminium aircraft hangar at London Airport, having a clear span of 125 ft.

Baird & Tatlock Dinner

Approximately 100 members of the staff were present at a dinner at the Waldorf Hotel, London, given by the directors of Baird and Tatlock (London) Ltd., on Wednesday, 7th January, 1953.

During the course of the evening, Mr. H. G. Chartres was congratulated upon his new appointment as Director and General Manager with Sciex East Africa, Nairobi, Kenya, the latest subsidiary of Scientific Exports (Great Britain) Ltd. Mr. Chartres, who has been with the Company for 23 years, and has held a number of responsible posts including that of Export Sales Manager since 1948, was presented with a suitably inscribed silver cigarette case as a token of recognition of his valuable service during the difficult post-war years.

Four other members of the staff, Messrs. Farmer, Harris, Tracey and Weathersbee were each presented with a gold watch commemorating the completion of fifty years service with the Company.

The Finishing of Aluminium and Its Alloys

By A. P. Fenn, A.M.I.Mech.E.
Birmingham Aluminium Casting (1903) *Co. Ltd.*

A range of surface finishing treatments may be applied to aluminium and its alloys in order to enhance the already good corrosion-resisting properties or to provide an improved surface appearance. They are discussed here under the following classifications : mechanical finishes ; paint finishes ; electroplate finishes ; anodised finishes ; and hard surface finishes.

THE last stage of the manufacture of many articles or component parts is a finishing operation, the method and type of finish adopted depending on the nature of the item concerned, the purpose for which it is designed, and the service conditions under which the completed structure is required to operate. Usually a surface is finished by a series of operations, with intermediate stages of cleaning and pre-treatment. The treatment applied to aluminium alloys, whether in the cast or wrought form, can generally be classified under one of the following types : (1) mechanical finish ; (2) paint finish ; (3) electroplate finish ; (4) anodised finish ; and (5) hard surface finish.

Details of the established techniques for these finishes can be obtained from articles which have appeared from time to time in the technical press. It is appreciated, however, that it is often a difficult matter to find the particular reference when it is urgently required. The Aluminium Development Association has prepared and issued a series of useful information bulletins* giving at length a large amount of detail concerning the best techniques for cleaning, pre-treatment and final finishing of all types of aluminium product. It is, accordingly, not intended to repeat this data, as those interested can obtain copies from the Association.

Cleaning

Thorough cleaning and degreasing of the surfaces to be finished is one of the first essentials of any successful finishing operation. It is not only necessary to remove the general dust and dirt, it is also essential that all mineral oil, blanking lubricants, and cutting fluids—which may be used in drilling and tapping operations—should be removed, together with soap emulsions used in blanking and pressing, and heavy soap-base drawing compounds ; swarf must also be removed.

The method adopted may be a manual operation, or, on the other hand, cleaning may be effected by immersion or vapour processes, according to circumstances. Hand cleaning by means of a swab and an organic solvent removes nearly all forms of contamination, and is the most practical method for very large structures and for articles that cannot be treated by immersion. Small work, of simple shape and in regular quantities, can be treated with a solvent or an alkali solution, the solvent being applied in liquid, spray, or vapour form—or by a combination of these—and the alkali in a bath or by a spray. Solvent vapour will remove mineral and pure oil lubricants and cutting fluids ; solvent spray, in conjunction with vapour, will remove soap emulsions and soap base compounds ; and a combination of solvent liquor and vapour removes swarf and general dirt and dust. Any of these methods, or combinations of them, can be used, depending upon the nature of the work to be cleaned and the requirements of subsequent processes.

Mechanical Finishes

The familiar processes of grinding, scurfing, and polishing, which are generally used successively for producing a highly polished finish on rough castings and forgings, are applied with the grades of material and speeds of operation appropriate to aluminium or the particular alloy from which the article is produced, as are the further processes of sand and shot blasting, scratch brushing, emery finishing, and polishing.

Sand blasting a surface roughens it uniformly, and the process is applied to aluminium alloy castings in order to smooth down rough surfaces, to remove core sand, and to clean surfaces stained by core compounds. It is applied to castings and sheet to produce decorative designs, or as a preparation for applied finishes. The process may also be used on forgings to remove flash marks. Grease must be removed before a surface is sand blasted. Various types of finish on the surface of both wrought and cast material can be obtained by adjusting the type and size of the abrasive, the air pressure, the angle and speed of impingement of abrasive, and the distance of the nozzle from the work. In general, a fine sand at low pressure is suitable for aluminium, the low pressure applying particularly to decorative work. Continuous operation is essential for a uniform finish, especially for a matt appearance, and where large sheets of aluminium are to be treated, machine sand blasting is found to be the best.

Steel or chilled-iron shot is used in the process of shot blasting, the shot being thrown against the surface by either a tangential force or by means of compressed air. The process not only produces an attractive finish but in many cases, has a beneficial effect on the fatigue strength of the material. To obtain the latter result it is essential to select round shot in preference to grit.

Satin finishes are produced on aluminium surfaces by means of scratch brushing ; in this process, brushes, preferably of stainless steel, are used, and are generally mechanically applied. The surface effect can be varied by altering the speed of the brushes and the hardness and diameter of the wire. Scratch brushing may be performed either wet or dry, and a finely-scratched surface is produced very rapidly by directing a small stream of water on to the brush while the work is being treated.

Aluminium takes barrel-polishing particularly well, and the process is often used for the purpose of burnish-

* A.D.A. Information Bulletin No. 13. Surface Finish of Aluminium and its Alloys.
A.D.A. Information Bulletin No. 14. Anodic Oxidation of Aluminium and its Alloys.
A.D.A. Information Bulletin No. 20. Painting Practice for Aluminium.

ing, rough grinding, flash removal, etc. Abrasives such as stones, wooden pegs, sawdust or other carriers, together with water, soap solution, oil, etc., are used, depending on the type of finish required. The speed of rotation of the barrel and the period of barrelling both affect the final result.

Paint Finishes

In many cases, aluminium products in service—both outdoors and indoors—are unpainted, the natural appearance of the metal being sufficiently pleasant, and its oxide film sufficiently protective, for many purposes. Occasionally, however, the need arises, for the purpose of decoration, or for added protection in corrosive conditions, for the application of paint to the surface of such parts. The complete process of painting for most metal surfaces comprises three well defined stages, cleaning the surface, preparing the surface to receive the paint, and applying the paint system. In the cleaning and preparation of aluminium surfaces, the same important general principles apply as for other surfaces.

Aluminium alloy castings, sand castings in particular, often provide a good paint key without any other treatment than degreasing. In other cases, particularly for wrought alloys, mechanical or chemical pre-treatments are to be recommended. Of the mechanical pre-treatments, shot blasting and grit blasting are useful for certain limited applications, and for sheet work scratch brushing has proved to be very satisfactory.

There are a number of chemical treatments developed specifically for the preparation of a surface suitable for painting, which are usually simple chemical dips followed by rinsing in water and drying. These treatments bring about some modification of the natural oxide film on aluminium, often increasing slightly its resistance to atmospheric attack, but principally forming an effective bond for the subsequent paint coat. Roughening of the surface by etching also provides a suitable key. Painting should be done fairly soon after chemical pre-treatment to reduce the risk of contamination or deterioration of the prepared metal surface.

While most of the chemical processes have been long established, a recent development is an acid chromate dip—a proprietary mixture known in this country as "Alocrom." This mixture can be used cold, when it requires between 5 and 10 minutes immersion, or hot, when only 1½–2 minutes is required. Because of this short cycle and the general flexibility of the process, it has been widely adopted for mass production. The use of phosphate coatings as a paint base on steel is well known, and mixtures suitable for use on aluminium have also been developed. A proprietary process Bonderite 170, which has recently been developed, enables steel, zinc, and aluminium to be treated in the same bath; it is, accordingly, extremely useful in suitable circumstances for the pre-treatment of components assembled ready for paint treatment.

The need for mechanical or chemical pre-treatment of the surface can sometimes be eliminated by the use of wash or etch primers. These primers have a vinyl-resin vehicle pigmented with zinc chromate, to which are added thinners containing phosphoric acid. The primer and thinners are packed separately, and when the two are mixed the solution has a usable life of up to 8 hours. A very good paint key is obtained with these primers, as the phosphoric acid reacts at the metal surface to produce an effective bond. The mixtures are preferably sprayed, but may be brushed on, and should be allowed to dry out and harden before the application of further paint coats. Exposure tests tend to show that the wash primers should not normally be considered as a replacement for the conventional zinc chromate primer when a fully protective system is required. The best protection is afforded by applying the zinc chromate primer as well as the initial wash primer.

The paint system to be applied to aluminium should be carefully chosen, having regard to the function of the component or structure. It may be a one-, two- or three-coat system, with primer and finishing coats chosen according to the service requirements. For instance, the finish may be of only a decorative nature, and a single coat system may be adequate. On the other hand, where conditions are particularly corrosive, three- or even four-coat paint systems may be needed to ensure good protection.

The choice of paint systems for aluminium is quite wide, and nearly all the common types are suitable—oil-base, cellulose, synthetic stove enamels, etc. Paints having salts of copper or mercury and metallic bronze or graphite powders are not to be recommended, in view of the danger of electro-chemical attack. There is also evidence that red-lead primers accelerate corrosion of the underlying metal in certain severe conditions; accordingly, lead-containing paints, especially primers, should be avoided.

In applying paint to aluminium, the normal methods, brush, spray, and dip, are used as appropriate, and no special technique is involved. The choice of the paint system is often best decided in consultation with the paint manufacturer. The single-coat system, mainly used for decorative purposes, consists of lacquers, stove enamel finishes, and special finishes, such as the crinkle or crystalline effects. The use of a single coat of clear lacquer is in regular application to preserve the brightness of mechanical and chemical finishes.

Where components are required to have a finish with greater hardness, adhesion, and resistance to moisture than can be obtained with air-drying paints or lacquers, the stoving paints and enamels are used. Alkyd resins are common vehicles for paints used on aluminium, the alkyd-urea resins being particularly chosen for pastel shades, and for applications such as refrigerator panels and the like. When using stove enamels, it is advisable to check to see that the temperature required for the stoving operation will not affect the mechanical properties of the alloy to be treated. The non-heat-treatable alloys, both wrought and cast, are virtually not affected at normal stoving temperatures. In the case of heat-treated alloys, particularly in the wrought field, it may be desirable to discuss with the suppliers of the material the effect of exposure to stove-enamelling temperatures.

For the production of components and structures exposed to the weather, a multi-coat system is usually desirable, consisting of a primer and one or more finishing coats. The priming coat must be considered in conjunction with the paint system as a whole, and it is desirable that the complete paint system should be supplied by one manufacturer to ensure mutual compatibility of coats. A priming paint for use on aluminium as on all other metals, should be adherent, protective, and compatible with the finishing coats. Adhesion is ensured by the correct pre-treatment of the metal, as

already mentioned. and is not impaired by expansion of the metal under heat.

Good protection of the metal depends in the first place on the careful choice of pigments and vehicles used in the paint. The choice of an inhibitive pigment in the primer increases the degree of protection, and one of the most satisfactory inhibitors on aluminium is zinc chromate. Amongst the finishing coats which offer good protection should be mentioned leafing aluminium paint, which has now reached a very high standard of quality in the hands of reputable manufacturers. Reference should also be made to bituminous paints, as these have been further developed of recent years, and it is claimed that such paints may now be pigmented with colour or with leafing aluminium flake to give a very durable finish, free from the strong tendency to bleeding through that is usually associated with this paint base.

Electroplated Finishes

By comparison with plating on other metals, the deposition on aluminium of a satisfactory electroplated finish has proved a difficult problem, due to the stable oxide film on the metal. Research on plating methods has been more intense during the last few years, however, and this has resulted in improvement of plating processes.

The zincate immersion process which imparts a zinc deposit to a properly prepared aluminium surface has been closely studied, both in this country and in the United States. This has lead to the formulation of immersion baths of optimum properties, thereby establishing this method of pre-plating aluminium on a firm basis of research knowledge. It is interesting to note that in America the A.S.T.M. has already published a tentative standard for pre-plating aluminium by the zinc immersion process. This is an indication that plating processes for aluminium are now becoming established and standardised.

The other process used with aluminium is based on a development of the Vogt process, and was described in a paper by A. W. Wallbank presented at the Spring 1952 Conference of the newly-formed Institute of Metal Finishing. This paper gives operational details of the process, which has been in regular use for a number of years and, coupled with skill and experience, has yielded plated products, particularly holloware, that have withstood many years service. The paper also mentioned, among other difficulties, the tendency of unsatisfactory immersion deposits being formed on aluminium during the first few seconds in the plating solution, due to aluminium being among the more anodic of the metals involved. An important distinction between the two zincate processes is the use, by Vogt, of electric current to deposit the initial zinc layer.

Plating techniques require modification for the treatment of different aluminium alloys, particularly casting alloys. Thus, the alloys containing appreciable quantities of silicon or magnesium are less amenable to plating, and success depends upon varying the plating condition to suit the alloy.

Both the foregoing processes offer considerable promise now that they have reached an advanced stage of development, and they are being successfully applied in electro-plating shops, but it cannot be claimed that either is so perfect that it can be adapted to automatic plating plants, which is the ultimate goal for any routine plating process for mass production; at the same time it can be recorded that the outlook is promising.

Anodised Finishes

Anodic oxidation, or anodising, is an electrolytic process for thickening the oxide film present on all aluminium surfaces. The process may be applied purely for decorative purposes, or to increase the natural high resistance of aluminium surfaces to corrosion, or to provide an insulating coat for an electrical conductor. Early patents covering this process were taken out in 1923 by Bengough and Stuart, and as others proceeded with experiments with different substances and metals, many other patents followed, but Bengough and Stuart are recognised as the originators of the process.

The main processes in use at the present time are the chromic acid process, the sulphuric acid process, and the oxalic acid process. The first, which was covered by the original patent already referred to, employs an electrolyte made up of a solution of chromic acid and water, and after the parts to be anodised are lowered into this electrolyte the current is switched on and the voltage raised gradually to 50. The film produced by this method tends to have a grey appearance and to be rather opaque.

The sulphuric acid process is possibly the most popular to-day; the electrolyte commonly used varies from about 15 to 20% by volume of sulphuric acid in water, and the process employs direct current at 10–15 volts. The time of treatment varies according to the type of film desired, which is also controlled by the temperature of the bath; the latter, rarely exceeds 25° C. Sulphuric acid films are transparent and colourless in themselves, taking the appearance of the metal on which they are formed.

The third, or oxalic acid, process uses that material in the electrolyte solution between 3 and 8% by weight. With this process, the electrolyte is usually maintained between 25° and 35° C. and a steady e.m.f. of between 50 and 60 volts is applied; alternating or direct current can be used. Films produced by the oxalic acid process using direct current are generally light straw colour, and those produced by alternating current vary from brass yellow, through gold, to bronze, with the exception of those on the silicon-rich alloys which remain grey.

For decorative purposes many of the films are dyed, and when this is the ultimate object of anodising, account must be taken of the fact that the three main anodising processes yield films which behave very differently towards dyestuffs. Films formed by the chromic acid process are opaque and range in colour from a light grey on pure aluminium, to a dark purple grey on silicon rich alloys. Accordingly, clear bright shades cannot be obtained on dyeing such films, and colours are often rather dull. The darker anodic films are only suitable for dyeing black. The oxalic acid films are semi-transparent and, as already stated, range from light straw to bronze. These films can be dyed in the usual way, but in most cases the resultant shades are affected by the colour of the films; thus, reds and yellows are very satisfactory, but good blues cannot be obtained.

Sulphuric acid films, on the other hand, being completely transparent and colourless, are ideal for dyeing. True, clear colours are obtained, and shades may range

Continued on page 90.

Aluminium and Its Alloys in 1952

Some Aspects of Research and Technical Progress Reported

By E. Elliott, A.Met., A.I.M.

Information Officer, The Aluminium Development Association

Attention is drawn to published work reporting research and technical progress in the various aspects of the metallurgy of aluminium and its alloys, including extraction, founding, fabrication, constitution and properties.

"HISTORY," said Henry Ford, "is bunk," and it is for these three words that he will be remembered in the years to come by grateful schoolboys who will never hear of the Model T or realise its effects, direct and indirect, upon the standard of life in America. However, another *pronunciamento* of the great man may appeal rather more to the technologist of to-day, and this one has come down to posterity as "I don't like reading—it musses up my mind." To keep fully abreast of the volume of papers, articles, pamphlets, books and other information which nowadays pours from the world's printing presses on his particular technical interest is becoming literally impossible for any one reader, and the present article does not pretend to be in any sense a summary of all that has been written on aluminium technology in 1952, even in Britain and America, to which countries it is mainly confined. It is rather an indication of the lines along which thought and effort are progressing.

Production

More than any previous year, 1952 has been a period of general interest in the expansion of production facilities for virgin aluminium throughout the world. This aspect is dealt with by West on page 65, so that only brief reference is necessary here to accounts which have appeared. A very useful global survey of the extraction industry is appearing in a series of articles[1], and when complete it will form a valuable source of reference, although no doubt events will require that it be frequently revised and amended. The most significant event in this country has been the issue of the White Paper[2] on the Volta River Scheme for the Gold Coast, which quickly proved a best-seller, and which sets forth clearly sound proposals for a great industry providing virgin aluminium within the sterling area.

In the New World, production is expanding in the United States, and in British Columbia the Kitimat development is proceeding rapidly[3]; the latter will eventually add half a million tons a year to Canada's ingot production capacity. All this will need vastly increased supplies of bauxite, and both America and Canada are looking to Jamaica[4] to provide a large part of the ore needed.

Melting and Casting

Apart from the senior engineering journals, not many technical publications have yet attained their first half-century, and the *Foundry Trade Journal* therefore celebrated its Golden Jubilee with some gusto, and the issue of a special number containing potted histories by well known authorities of various branches of the foundry trade. West[5], in his survey of progress in the casting of aluminium and its alloys, was able to point out that the fifty years cover practically the whole history of the engineering applications of these metals, and his use of the word "phenomenal" to describe the growth of the industry seems fully justified, especially when one turns the pages of the special issue and realises that all the other metals considered were known to the ancients.

Two interesting papers have appeared during the year dealing with the true viscosity of aluminium and its alloys, using different experimental methods. Yao and Kondic[6], working with several pure metals, including 99·9935% aluminium, in an oscillating pendulum apparatus, showed that their viscosity values agreed well with those generally accepted, except at temperatures very close to the melting point. Quite small additions of titanium, of the order of 0·05–0·2%, appreciably increased the viscosity of aluminium, and, as might be expected, the viscosity of the commercially-pure metal was shown to be considerably greater than that of the super-pure metal used. The investigation of Jones and Bartlett[7] was confined to aluminium and its binary alloys, using a rotating-cylinder method, and they give viscosity-temperature curves for aluminium-silicon, aluminium-zinc, aluminium-magnesium and aluminium-nickel alloys of various compositions. Two interesting observations are that all the alloys show a characteristic change-point at 760°–770° C. above which viscosity is practically constant, and that viscosity varies in accordance with the equilibrium diagram. A welcome addition to the knowledge of modification of eutectic aluminium-silicon alloys is that it results in an increase in viscosity of 30%, a phenomenon which, the authors suggest, should prove a fruitful field for further work.

An eminent authority on aluminium alloy castings recalls being told of a cynical customer's impression that a blow-hole was the essential nucleus around which a casting was formed, and his opinion may have had some legitimate basis two or three decades ago. Brace[8] has shown, however, that the position is now much improved, and his review of methods of gas removal before casting illustrates how the results of work by the National Physical Laboratory and the British Non-Ferrous Metals Research Association have been applied in foundry practice, so that to-day the use of chlorine or chlorine-containing compounds to remove hydrogen has become a standard procedure.

Despite the increase in knowledge of how to produce sound castings, it is still the case that, particularly with certain alloys, it is difficult or impossible to guarantee pressure-tightness, and recourse must be had to some form of impregnation. A useful summary of methods of doing this has been made by Hull[9], and is notable for its conciseness, covering as it does five methods and four types of impregnating material.

Another important aspect of quality in aluminium and its alloys upon which important research has been done by the B.N.F.M.R.A. is that of grain refinement, and Cibula[10] has provided a useful summary of the present state of knowledge, not only as regards aluminium, but for several other non-ferrous metals. The effects of titanium and of boron, and of the two elements together, are set forth, and reference is made to the ingenious method of centrifuging by means of which it was shown that removal of titanium carbide nuclei resulted in coarse grain, thus establishing the mechanism of grain refinement. Much reference to this British work is made by Bernstein[11] who feels that more research is required into grain refinement in light alloys, in order to ascertain the effect and relative importance of the various factors producing it.

Dodd has used an aluminium forging alloy to B.S.2L42 (equivalent to HF18 in B.S.1472) to assess residual stress in sand castings[12] and in chill-cast billets[13], by the application of electrical-resistance strain gauges to the measurement of dimensional changes on sectioning or boring. The effect of a number of variables has been studied, such as water in the sand, pouring temperature, and rate of pouring, and some work has also been done on a duralumin-type alloy semi-continuously cast. It is a little sad to read at the end of the paper on sand castings that the author considers that, except that he has established the merits of early stripping, his work is of doubtful practical value. This may at one time have been said of much research which has eventually proved of revolutionary significance, and while the applied scientist cannot emulate the pure scientist's search for knowledge for its own sake, he must not expect to see immediate benefit from all his investigations.

The past year has seen an increase of interest in relatively new foundry methods, including shell moulding, plaster-moulding and the use of semi-permanent moulds for series of, say, up to 400 castings. Details[14,15] have been published of the shell moulding process, using sand and a thermo-setting plastic resin, illustrated by some very clear pictures of the technique and its products. The figures for dimensional accuracy certainly seem impressive, showing improvements of the order of ten times when compared with sand castings, and at a cost which is claimed to be much lower than that of sand moulds. Semi-permanent ceramic moulds have been described by Hope[16] and their value for making accurate castings with a good finish in quantities too small for gravity die casting is well brought out. The Antioch[17] process of plaster moulding may now be regarded as well-established and forms a useful solution to the problem of producing aluminium alloy castings with great accuracy, notably tyre moulds previously made from steel at high cost.

Although the title of his article suggests that foundries in the United States are on the threshold of great changes in technique, Harris[18] seems chiefly concerned to establish that castings can replace forgings in highly stressed structures such as aircraft. He refers to the dimensional accuracy to which castings can now be produced and their facility for the reproduction of complex shapes, and goes on to claim that American foundries are regularly making commercially aluminium alloy castings with ultimate tensile strengths well over 27 tons/sq. in., yield points above 22 tons/sq. in., and elongations exceeding 10%. The composition of the alloy is not mentioned. Harris refers to the dictum of a well-known American industrialist, much quoted recently, that " You can't do to-day's job with yesterday's tools and be in business to-morrow," and the significance of this attitude is inherent in the article.

Other American authors[19,20] are taking interest in the use of light metal castings in aircraft, and they too emphasise the dimensional accuracy which can be attained. The fact that castings do not suffer from directional effects as do some wrought products is also stressed, and the difficulty of casting thin sections brought out. In general, the reader feels that there may have been more realisation in this country of the value of castings for aircraft applications, and that the Americans are now beginning to appreciate the possibilities, although they are, perhaps, a little sanguine in their estimates.

Considerable interest was aroused towards the end of the year by the Symposium on Aluminium Alloy Castings held in Birmingham and London by the Aluminium Development Association, accompanied by an exhibition illustrating, *inter alia*, advances in casting technique. Publication of the papers presented and the resulting discussions is shortly expected.

Heat Treatment

Once again the Institute of Metals has held a Symposium on an important aspect of the manufacture of semi-fabricated products in non-ferrous metals, this time devoted to equipment for heat-treatment, and again a number of excellent papers stimulated a valuable discussion. Evans[21] and his co-authors deal with electric heating, and after an introductory section on furnace construction, control, and loading, consider aluminium and magnesium alloys separately from other non-ferrous metals, in view of the limited temperature ranges necessary. The requirements for the various types of treatment—annealing, solution treatment, and precipitation treatment—are reviewed, and the methods of meeting them set forth, including salt baths, forced-air-circulation batch furnaces, and chain conveyor furnaces for continuous use, with a mention of flash annealing. The practical problems to be expected are noted, as are the methods of dealing with them. Gas equipment is described by Waight[22] and he provides much technical detail about the theory of heat transfer, and the design of burner systems, advocating strongly the use of automatic mixture control devices. Furnace design also receives considerable attention, and the reader is perhaps a little surprised to note the author's hope at the end of the paper, that the omission of more detailed treatment will not obscure the fact that the art of designing gas-fired furnaces is no longer dependent upon empiricism ; this has certainly been well established in the paper. Paton[23] deals with the batch heat-treatment of aluminium alloys from the point of view of a furnace user, and perhaps the most interesting part of his paper is his list of criticisms of current designs, which will no doubt receive earnest consideration from the furnace manufacturers, particularly the one stated

to be common, namely, that in the present air furnaces both thermal input and rate of air circulation are too low.

Flash annealing is relatively new in the aluminium industry, and Staples[24] gives a very full and detailed account of his experience with it, bringing out clearly its effect on the quality of material produced, particularly as regards grain size. No important detail of equipment design or operation seems to be omitted, and the paper should prove very useful to those contemplating this method of working. Lamourdedieu[25], introducing a cosmopolitan facet to the Symposium, describes collaborative work by the Société Centrale des Alliages Légers at Issoire and the Pittsburgh United Engineering and Foundry Company, on the design and construction of equipment employing induction heating for the solution treatment of duralumin-type alloys. A problem of particular interest is that of measuring the temperature of the moving strip, since accuracy is essential if the required properties are to be attained, and the danger of overheating eliminated. A special type of radiation pyrometer is described, but the author admits that practical experience with it gives variable results, to quote, "sometimes very good, sometimes bad," and modifications are being tried. A possible criticism of the general equipment might be that it employs spray quenching, considered by some observers to result in sheet of lower corrosion resistance than that quenched directly in water.

Mention should be made of the excellent photographs illustrating several of the papers to the Symposium, since they enable the reader to grasp many of the author's points so much more readily than if only the text were available.

The subject of induction heating for the continuous heat-treatment of aluminium alloy sheet and strip has also been the subject of an article by Hull and Scott[26] and their views are largely in line with those of Lamourdedieu. Production experience now seems to be the main requirement before further progress can be made with this type of heat treatment.

Joining

No news, according to the saying, is good news, and the fact that 1952 has not seen many papers on changes in the technique of welding aluminium and its alloys illustrates that a position of consolidation has been reached. During the past five years, tremendous strides have been made in this branch of industry, and fabricators in light alloys are now able to make welded joints with a facility and speed hitherto quite impossible. The chief direction in which the advance has been made is, of course, towards argon-arc welding and its progeny, consumable-electrode shielded-arc welding, but the metal-arc process is also in regular and increasing use for applications where it shows advantages, and the availability of improved electrodes has helped this tendency. For certain joints, non-corrosive fluxes are removing one of the drawbacks from manual oxy-acetylene welding of aluminium.

Houldcroft[27] has summarised this progress in welding light alloys, and he draws attention to the present necessity for devoting some attention to materials, illustrating his meaning by reference to the work of the British Welding Research Association on aluminium-magnesium alloys in avoiding porosity in the fusion zone. He points out the value of using special welding-quality plate, a procedure adopted in other metal industries. The adverse effect of alkali metals on the strength of metal-arc welds is also quoted to show the importance of developing still further improved welding electrodes.

There has been a number of interesting accounts of the use of fusion welding in widely different forms of construction, perhaps the most noteworthy being in connection with marine applications of aluminium. A Thames pleasure vessel with a noble name, the motor launch *Queen Elizabeth*, has recently been provided with a new superstructure, and the opportunity was taken to assemble it by the consumable-electrode shielded-arc process. A brief description of the work[28] has been published, with the information that a full report is being prepared for the Ministry of Supply, who lent the Aircomatic equipment used. The assembly was carried out completely successfully, about 1,000 ft. of weld being laid down, plate in alloy NP5/6 (aluminium–4¼% magnesium), and sections in alloy HE10 (aluminium–magnesium–silicon, heat-treated), being involved, together with some 20,000 ft. of filler wire in alloy NW6 (aluminium–5% magnesium), which is now available in this country with the special high quality finish necessary for this mode of welding. Another type of vessel for which aluminium construction has been found very advantageous is the shallow draught barge, and a design named the "51 barge" employs argon-arc welding ingeniously. Instead of fabrication from plate, the shell plating is made from extrusions incorporating their own stiffening members, and these are joined by longitudinal argon-arc welds in continuous runs up to 30 feet. An article[29] describing this design and mode of construction was published in connection with the news that 60 of these vessels had been ordered for use in the Belgian Congo, where their shallow draught will be vitally important.

A description[30] has appeared of yet another marine use of aluminium alloys facilitated by shielded-arc welding, although in this instance ship's equipment rather than the vessel itself is concerned. Aluminium alloy under-frames are made for mounting generating sets incorporating diesel engines in the 200 to 800 b.h.p. range, and these frames are fabricated from plate and sections in aluminium-magnesium alloy. For this process Aircomatic equipment is used, and the account draws attention to the necessity for having argon of high purity if the welds produced are to be of optimum quality. Details are given of the technique found best for this particular welding job.

There is a good deal of experience of repairing cracked and fractured aluminium alloy castings by welding, but a recent brief note[31] describing such a repair has some noteworthy special features. Not only were the castings —end shields of an alternator—very large, but they were subjected to high stresses as a result of variation in speed of rotation. The method of providing a flexible joint to prevent further cracking seems particularly ingenious involving as it does, bolted reinforcing plates welded at either side to each half of the end plate. Metal-arc welding was used for this repair.

Turning from fusion welding to other methods of joining, yet another method developed during the past half-decade is now well established. Tylecote[32] has reviewed the process of pressure welding as applied to ferrous and non-ferrous metals, including the effect of a number of variables on method of working and upon the

resulting joints, mainly lap joints in sheet and butt joints in bars and sections. Both normal and elevated-temperature techniques are covered.

While much progress has been made in the development of soft-soldering methods, this method of joining is still not so readily applicable to aluminium as to many other metals, there being difficulties associated both with technique and with the resulting joint, either from embrittlement or susceptibility to electrolytic corrosion. This last can be avoided, either by protection of the joint or by the use of high zinc solders, but a completely satisfactory method of hand soldering with an iron remains elusive, complete removal of the oxide film being the problem. That some progress has been made, however, is shown by Neppiras[33], who has described the ultrasonic soldering of aluminium with a hand iron incorporating a magnetostriction transducer which produces vibrations which perforate the oxide film by cavitation phenomena in the molten solder. This principle has also been applied to molten solder baths, in which wires may be dipped for tinning. The author is careful to point out, however, that the problem has only been simplified, not entirely solved, since there are metallurgical aspects still requiring investigation; nevertheless, successful continuous tinning of aluminium has been carried out on a laboratory scale. A practical application of ultrasonic soldering in the foundry is the subject of another article[34], the principal uses being the repair of superficial defects in aluminium alloy castings, and the modification of aluminium patterns.

Another relatively new method of joining aluminium is to glue it together, or, to give the process its correct title, to bond it by means of synthetic resin adhesives. The aircraft industry has rapidly seen the advantages of this procedure, and some well-known aircraft make considerable use of it. Parker[35] has described how the process is applied by one aircraft company, and he quotes average shear values for bonded joints of 2,200 lb. on a joint 0·5 in. by 1 in. and 60 lb. "peel." This latter test has been specially developed for this type of joint, and consists of "peeling" the joint apart against an autographically recorded loading device. The results are used comparatively, to provide a ready measure of the quality of the joint, as a means of checking the process. The author lists practical advantages of metal bonding, including reduction in weight, improvement of surface finish, reduction of stress concentrations and lower cost. A good case is made out for the use of the process in aircraft construction, wherever conditions are suitable for it.

The general survey by Beatson and Brooker[36] of industrial brazing includes aluminium, and gives details of the design and strength of joints and the various methods of making them.

Constitution

In metallurgy, familiarity with the mechanical and physical properties of materials and, indeed, their extensive application commercially, usually precedes the establishment of fundamental knowledge about the alloy series to which they belong. The assembly of ternary equilibrium diagrams involves long, skilled and painstaking work, and it is good to see that progress has been made in the investigations at the University of Birmingham by Raynor and his collaborators, papers having appeared on the aluminium-chromium-zinc[37] and aluminium-chromium-iron[38] systems. Metallographic and X-ray methods have been used, combined with chemical analysis of primary crystals extracted from slowly cooled alloys. As in previous reports, the authors include some excellent photographs of separate crystals of intermetallic compounds. The work forms part of a general programme on aluminium-rich ternary alloys containing as solutes two transition metals or one transition and one non-transition metal, and this, when complete, will represent a major advance in knowledge of the constitution of aluminium alloys.

Axon has commenced the investigation of the aluminium-copper-magnesium-silicon series of alloys, and his first report[39] reveals the complexity of the field. He has studied the equilibrium isothermal at 460° C. and has encountered six phases giving rise to fourteen separate phase fields. Ellwood[40] has determined the lattice spacings and densities of solid solutions of copper, magnesium and silver in aluminium at 250° C. and noted anomalies in the case of the last two, deducing that they are caused by Brillouin-zone overlaps. The author tentatively suggests that the initial curvature of the aluminium-magnesium lattice-spacing/composition curve is associated with the formation of vacant lattice sites which lead to reduced lattice spacing. This phenomenon has also been investigated by Poole and Axon[41], who find that increasing the purity of the magnesium reduces the curvature of the relationship at low concentrations of magnesium, and causes the linear portion of the curve to become more steep. These workers have studied lattice spacing in the ternary aluminium-magnesium-copper solid solution, and report difficulty in accurate control of alloy composition. Ellwood has also measured the lattice spacings of solid solutions of zinc in aluminium[42] at room and elevated temperatures, with results that resemble in some respects those he obtains with magnesium and silver in aluminium.

By microscopical examination and electrical resistance measurements, the latter proving a very sensitive means of determining small structural changes, Rotherham and Larke[43] have drawn the solid solubility curve of silver in aluminium up to 8% silver. Interest in the effect of cadmium on the ageing properties of aluminium-copper alloys has increased recently and Hardy[44] has estimated metallographically the solubility of this element and of indium and tin in aluminium at temperatures of 530° C. and above. The maximum solubilities are shown to be low in all cases, and tin is interesting in that it has a retrograde curve, its maximum solubility of 0·1% being at about 610° C.

Properties

Despite certain advantages enjoyed by a metal of relatively low modulus of elasticity, the idea of being able to increase the level of this property in aluminium alloys without loss of other valuable qualities is very attractive. That the difficulties are great has been demonstrated by investigation in the past, and recent work by Dudzinski[45] confirms that large quantities of alloying additions are necessary to have any noteworthy effect. Thus, in binary alloys, chromium increases Young's Modulus by less than 500,000 lb./sq. in. for a 1% addition, and this is the best element from this point of view amongst those tried.

Recent co-operative work in the aluminium industry has shown that high strength aluminium-zinc-magnesium-copper alloys may be extruded more readily than was at one time thought, provided that the optimum

composition is selected from the rather wide limits permitted by specifications. Wilson[46] has traced development work on these alloys, and summarised their production, heat-treatment, and properties at normal and elevated temperatures.

There has been a number of articles giving information about the texture of aluminium under various conditions. Thus Calnan and Williams[47] have questioned whether the texture end points of aluminium under pure tension are the [111] or [100] as previously supposed, adducing evidence that they lie on the (011) zone between these two points. Beck and his collaborators have investigated rolling textures[48] and annealing textures[49] in face-centred cubic metals, including aluminium, and shown that in the former case the texture is independent of the incidence of cross-rolling. In high-purity aluminium, annealing of rolled material results largely in a retention of rolling texture, orientation of recrystallised grains being similar to an orientation prevalent in the material as rolled.

Grain size and shape, and the effect of flow upon them, have also received the attention of investigators, Williams and Smith[50] describing the application of stereoscopic radiography to the study of three-dimensional grain shape in a worked and annealed aluminium-tin alloy. The large stereoscopic illustrations in this paper are noteworthy, and have a definite beauty, quite apart from their technical interest. Tate and McLean[51] have noted a sub-crystal structure in cold-rolled aluminium, and suggest that the sub-crystals may be the germs of recrystallisation, certain of them growing at the expense of others.

Ramsey[52] has studied the sub-grain structure in coarse-grained aluminium deformed at elevated temperatures, and he concludes that it resembles that resulting from heating after straining at room temperature, being associated with banding similar to kink bands. Rachinger[53] also refers to a deformation-induced sub-structure within the grains in describing his work on slowly deformed aluminium, and he indicates that, for a given temperature and rate of straining, the effect of an increase in grain-size is roughly equivalent to that of a decrease in temperature, or an increase in strain rate. In a further investigation[54], the same author has shown that as temperature increases and rates of deformation decrease, external changes of form are due increasingly to relative grain movement rather than to elongation of individual grains. Again, under creep conditions, while the extreme surface of the metal shows much grain elongation, the grains in the centre of the mass are little deformed, but move relative to one another. These phenomena are illustrated in an appendix by soap bubble models in the Bragg manner.

Urie and Wain[55] have used a grid, photographically reproduced on the surfaces of specimens, to measure elongations in individual grains of coarse-grained aluminium after plastic deformation. Variation in elongation between grains was noted, and also within individual grains, there being deformation bands produced in the specimen increasing in magnitude with the overall elongation.

The effect upon recovery after stress of the presence of banding is brought out by comparing results given in two papers on recovery and recrystallisation. Thus Chen and Mathewson[56] have annealed single crystals of aluminium and shown that crystals with deformation bands are more susceptible to recovery than other crystals, and that the orientation of the new grains can be forecast. Ramsey[57], working with polycrystalline aluminium, shows that only a few grains recovered to a great extent, the majority doing so only partially, recovery depending upon the presence of kink bands, and its degree varying with the closeness of packing of the bands.

Servi, Norton and Grant[58] have used metallographic and back-reflection X-ray techniques to study sub-grain formation in coarse-grained high purity aluminium. They found that the average size of the sub-grains varied inversely with applied stress, and that their orientation suggests that the slip process is the primary mechanism of deformation even at elevated temperatures, the difference in behaviour of specimens at high and low temperatures being a function not of the grains, but of the grain boundaries. One of these observers, Grant, has collaborated with Chang[59] in a study of creep of the grain boundary, also in coarse-grained high purity aluminium. They conclude that the mechanism of creep at the boundaries is an alternating boundary sliding and migration, causing deformation within the grains, and some convincing photomicrographs are given in support of this theory. Crystal slip of high purity aluminium during creep has also been investigated by McLean[60,61] who, working with specimens at 200° C., observed two types of slip bands, prominent and fine, the former being zones of concentration of the latter, and increasing in number with increasing grain size and stress, but in no case representing more than half the total strain. Using a plastic replica technique with the electron microscope, Trotter[62] has also examined McLean's specimens, and found that the slip zones consist of intimate segments of primary and cross-slip, and that they do not coincide in direction with slip-planes. Both McLean and Trotter include some excellent photomicrographs with their accounts.

Wood and Suiter[63] have subjected to slow deformation at elevated temperatures specimens of aluminium in which the grains had already been broken down to a substructure during creep. Growth of this structure was shown to be greater during simultaneous heating and straining than that induced by heating only, and the phenomenon is therefore termed " stress recovery." As might be expected, the strength of the specimen was shown to be inversely proportional to the size of the substructure, for given conditions of deformation. Similarly Greenough and her collaborators[64] have found that, with an aluminium-silver alloy quickly pulled at 20° C. or 300° C., whereas annealing at 300° C. in the absence of stress caused little recovery, cell development occurred in creep at this temperature.

In an attempt to apply current theories of creep to tests in torsion on tubular specimens, Johnson and Frost[65] have used an alloy to B.S.2L42 (equivalent to HF18 in B.S.1472) at various temperatures. Their chief conclusion is that no fundamental explanation accounts for the transient creep at any of these temperatures, and they postulate a new formula applicable up to 150° C., above which they reason that no equation seems likely to hold.

Two interesting accounts have appeared of ingenious methods of investigating slip, in one case by Chen and Pond[66] on aluminium, and in the other, by Kramer and Maddin[67], on brass and aluminium. The former work employed a cine-camera to take successive photographs during testing at normal temperature, and prints

selected from a sequence reveal clearly the development of slip bands during progressive straining. The authors measure rates of propagation, and conclude that unit slip is a shearing of a row of atoms and the growth of a slip band the joining in of successive rows. Kramer and Maddin used single crystals, and a pendulum method of applying stress for very short periods, removing the crystal for examination after each increment of stress. Strain measurements were made by a strain gauge incorporating an oscillograph, photographs of the trace providing a strain/time curve. No delay time before slipping was found in aluminium even with impact times as low as 8×10^{-5} seconds, but a delay dependent upon temperature was observed in β-brass.

Continuing his work on the properties of aluminium-copper-cadmium alloys, Hardy[68] has drawn hardness/ageing-time curves for aluminium-copper alloys containing cadmium, indium or tin. In discussing the results, he suggests that the improved hardening, compared with binary aluminium-copper alloys, is due to the third element facilitating the nucleation of the Guinier-Preston zones, possibly associated with prior precipitation of atoms of that element, or grouping of copper atoms round them during solution treatment.

Zirconium is becoming a popular alloying element, and Tournaire and Renouard[69] have investigated its effect upon duralumin of the type covered by HF15 in B.S.1472. Replacing the manganese by the maximum possible addition of zirconium, 0·25%, they find that the resulting alloy has mechanical properties equal to the conventional material, and a fine and uniform grain size and greater forgeability and castability. Lyons and Pumphrey[70] have published an account of their work on high temperature properties of binary alloys of aluminium with copper, iron, manganese and zinc, as they affect the welding and casting properties of these materials. These investigations formed part of the well-known research on the welding of aluminium and its alloys by the team led by Dr. Pumphrey at the University of Birmingham.

The shipbuilding applications of aluminium alloys have been prominent in 1952, and Corlett[71] has considered how the properties of alloys most used for this purpose fit them for it, and how they affect the processes and manipulations carried out in the shipyard. This account is a useful summary for those first approaching aluminium as a material for marine construction.

Powder metallurgy is a comparative newcomer amongst the industrial arts, and its application to aluminium only recent, but interest continues in the material developed in Switzerland with the perhaps rather unfortunate title in English eyes of S.A.P. (Sinter-Aluminium-Pulver). The excellent properties offered by this material, particularly at elevated temperatures, have been described[72,73], together with some account of its development and methods of manufacture. The point is well brought out that it is a metal/ceramic complex, and partakes to some extent of the advantages of both forms of matter. One author complains of lack of attention to S.A.P. by investigators and manufacturers, but possibly economics may be blamed for this state of affairs. The title of a paper by Lyle[74] encourages the reader to expect information about applications, but he deals only with properties, and refers to possible uses only briefly in his concluding paragraph.

Corrosion and Protection

Much information has been published through the years on the effect of various impurities on the corrosion resistance of aluminium, and Whitaker[75] has performed a signal service by reviewing the available literature and providing a summary of the ground covered in no less than 175 references. Her brief conclusions are cautious, but in less than a page they indicate the present position of knowledge on this important subject, and are invaluable to both engineer and research worker.

In a paper on the anodic film on aluminium, Phillips[76] considers the nature of coatings produced by different anodising methods, and draws attention to their respective merits and fields of application. The protective value against corrosion of suitable films is illustrated by the results of atmospheric and salt-spray tests. An important recent development in anodising technique has been the construction of units for the continuous treatment of strip, often combined with lacquering, principally for the subsequent production of aluminium cans for food preservation. The process has been described as used in Norway[77], where a considerable tonnage of aluminium is treated in this way every year. In addition to its resistance to corrosive media, the anodic film is, of course, noted for its hardness and resistance to abrasion. The provision of an abrasion resistant surface on aluminium, in other words, the case-hardening of the metal, is highly desirable in many applications, and Campbell's[78] paper on the production and properties of thick anodic coatings aroused considerable interest. Films over ten thousandths of an inch thick are mentioned, although for most engineering purposes a quarter of this thickness is stated to be adequate. Further developments of the process are awaited, both as regards technique of production, and fields of application. Another method of providing a hard surface on metals is by hard chromium plating, and Mayer-Rässler[79], in a paper to the Fourth International Mechanical Engineering Congress, has shown how difficulties have been overcome in the use of this process with aluminium. Adhesion is secured by the sodium zincate process, or by a nickel chloride pickle; in the latter case, the nickel deposit is removed by nitric acid immediately before chromium plating. The usual thickness of coating is about a tenth of a millimetre, and the principal application hitherto has been to aluminium alloy cylinder bores. Wallbank[80] has described works processes used in the production plating of aluminium, all dependent upon the preliminary electro-deposition of a thin coating of zinc. The technique is simpler than the well-known zincate process, and may be applied to the great majority of the commercial aluminium alloys.

Turning from electro-plating to the more general aspects of finishing aluminium and its alloys, recent developments have been reviewed by Brace[81] and his account reveals the considerable steps that have been taken since the war, particularly in methods of preparation for painting. The last section of his article deals with vitreous enamels, and he notes that no completely satisfactory finish of this type has yet been developed for aluminium, despite intensive research in this country and in America.

The high corrosion resistance of aluminium has resulted in its increasing use for the protection of iron and steel. In the present state of knowledge it cannot be plated from aqueous solutions, and electro-deposition

of aluminium is not used to any extent commercially, although Lamb[82] notes the development of an organic bath consisting of aluminium chloride dissolved in ether, with the addition of lithium or aluminium hydrides. The chief methods of application of aluminium to steel have been summarised by Moses and Popham[83], including spraying, calorising, hot dipping, cladding by rolling, casting-on, electro-plating, and the vapour reaction process. Calorising is well established, but of the others only spraying is much used in this country, although aluminium-clad steel sheet is available in the United States. Weber[84] has reviewed the cladding of metals generally, by rolling and by casting-on. He make some reference to the cladding of duralumin-type alloys with pure aluminium, and sees advantages in the casting-on process as compared with rolling, which is contrary to British production experience. Metallising by spraying is receiving a good deal of attention, and Keller[85] has described the process and its applications, including the building up of worn parts and the protection of ferrous metals, either alone, or in combination with paint finishes. The protection aspect has also been considered by Ballard[86] who gives details of the pretreatment by grit blasting required to ensure good adhesion of aluminium or zinc to steel: this procedure cleans and roughens the surface. The method of spraying described is the wire pistol. Stanbridge[87], in a companion paper to that of Ballard, gives practical details of experience with aluminium spraying on structural steelwork. He draws attention to the necessity for further investigation of the welding of steel sprayed with aluminium or zinc, in order to achieve welds of full strength, as against those of about two-thirds strength at present being made. No mention of this difficulty is made by Clift[88] in his account of the use of zinc or aluminium-sprayed tubes in structural work, although he emphasises the importance of "touching-up" the weld area with spray after welding The illustrations of mechanical grit-blasting and metal spraying of tubes are very informative.

Applications

Many accounts of varying technical content appear concerning uses of aluminium and its alloys, and a small selection will serve to illustrate interesting applications during 1952. The most striking and largest single use was not, regrettably, in this country, and indeed resulted in Britain losing the semi-mythical blue riband of the Atlantic. Two thousand tons of aluminium alloy in the superstructure of the liner *United States* form the largest aluminium structure yet made anywhere, and its effect upon the speed and stability of the vessel are now represented in the record books. Little technical detail of the construction is available although some semi-popular accounts have been given[89].

Amongst smaller craft, the largest all-aluminium yacht[90] has been constructed in Devon by the "two-way tension" method, and the Railton-Vosper boat powered by jet, which ended so disastrously with the death of Mr. John Cobb, was a revolutionary design employing a good deal of aluminium alloy[91].

In the building field, aluminium glazing bars and corrugated sheet have been used for re-roofing part of the Alexandra Palace[92]. Railways in this country have not made extensive use of aluminium, outside the London Underground, and the contrasting position in France is brought out by Grindrod's[93] description of aluminium alloy mineral wagons there.

The increasing use of aluminium in the electrical industries is one of the features of the past two or three years, and cable sheathing is an application where the metal has several technical advantages over traditional materials in addition to its economic attractions. Two methods of sheathing have been described, one involving the cold-sinking of oversize tube on to the cable[94] and the other the longitudinal welding of the sheath by the argon-arc process, gripping of the cable being ensured by circumferential corrugation in a special machine[95]. It is diverting to read that in initial work with the former method the company concerned erected and dismantled the experimental plant every week-end to prevent its being seen and the secret leaking out.

Standards

Having begun this article with a reference to Henry Ford and the Model T, let us recall another of his sayings which might be described as an elementary statement on standardisation, or, at any rate, simplification. Asked about the finish to be applied to that famous car he is reported as replying: "Any colour will do so long as it's black." Standardisation is a little more complicated nowadays, and Hutt[96] has reviewed the present position of specifications for aircraft materials, including cast and wrought aluminium alloys, and since his article appeared new documents have been issued covering the doubly heat-treatable duralumin-type alloys in various forms, representing a rationalisation of the position of this material, all the compositions being identical and of the variety known so long to light alloy metallurgists as "X." In the general engineering field, no new standards have appeared for aluminium and its alloys, as the series is complete, and a period of consolidation will now be necessary followed by any revisions which experience shows to be essential.

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Dr. Chesters Honoured in U.S.A.

THE Board of Directors of the American Institute of Mining and Metallurgical Engineers recently announced that the Robert W. Hunt award for 1953 would be given to Dr. J. H. Chesters, for his paper entitled "Flow Patterns in Open-Hearth Furnaces" presented at the 1951 Conference at Cleveland, Ohio, and subsequently published in the "Open-Hearth Proceedings." The Hunt award was established in 1920 to commemorate a distinguished American metallurgist, and recipients are nominated by a continuing committee of four members of the Iron and Steel Division, together with the Chairman. The award is made for the best original paper or papers on iron and steel contributed to the Institute during the period under review.

Dr. Chesters was educated in Nottingham and Sheffield and at the University of Sheffield. He held the Robert Blair Fellowship in Berlin in 1931–32, and between 1932 and 1934 a Commonwealth Fund Fellowship at the University of Illinois, where he studied ceramic engineering. He was awarded the Sir Robert Hadfield Medal in 1946 and is the author of books on iron and steel and steel plant refractories, and of many papers and technical articles. Dr. Chesters was President of the British Ceramic Society (1951/52) and of the Sheffield University Metallurgical Society (1951/53); he is also a Member of Council of the British Ceramic Research Association, Chairman of the All-Basic Furnace Sub-Committee (B.I.S.R.A.–B.C.R.A.) and Chairman of the Open-Hearth Instruments Sub-Committee of B.I.S.R.A.

Transformation Characteristics of Nickel Steels

ISOTHERMAL transformation diagrams for the principal nickel alloy steels were published in the form of a book by The Mond Nickel Co. Ltd. two years ago. A revised edition of this book has now been issued with the important addition of Jominy end-quench curves for each of the steels examined. The Jominy end-quench test is useful in assessing the hardenability of a steel at different ruling sections. Using the data given in this book it is possible to forecast whether a bar of given size will harden fully, harden partially or transform completely to the soft state when quenched in oil. Copies are available free from the Company at Sunderland House, Curzon Street, London, W.1.

The Joining of Aluminium and Its Alloys

By W. V. Binstead

Joining Engineer, Northern Aluminium Co., Ltd.

The joining of light alloys by methods other than mechanical ones is not nearly so formidable a problem as many people still imagine it to be. In this article, the author discusses briefly the various methods of welding, brazing and soldering which are available, giving the advantages and disadvantages in each case.

THE joining of aluminium and its alloys is a subject which has been pressed forward during the past few years with considerable urgency and speed, and perhaps because of this, it has appeared, and indeed still does appear to some welders, to have developed surrounded by a certain air of mystery. The truth is, in fact, that the problems encountered in light-alloy joining do not differ greatly in character from those met with when joining other materials by like processes. These problems occur as a result of the application of heat during welding and brazing, and providing certain fundamentals are recognised, then the joining of light alloys by means of the application of heat should not offer any real difficulty.

Aluminium alloys may be divided into two distinct classes, namely, work-hardening alloys and heat-treatable ones. The first group contains those materials which rely upon the application of cold work to the metal for the purpose of increasing strength and hardness values, while materials of the second group depend, as the name implies, upon a form of heat treatment to increase one or more of the mechanical or physical properties.

Heat treatment of all heat-treatable alloys, however, should be carried out under controlled temperature conditions; briefly, it consists of uniformly heating the metal to a temperature in the region of 500° C. followed by rapid cooling, followed in some cases by a second heat treatment at a much lower temperature for a longer period of time.

During certain joining processes, the normal heat-treatment temperatures are inevitably exceeded, resulting in structural changes within the metal in the joint vicinity. It is because of the complex metallurgical changes which occur, that we, in this country, do not recommend the joining of certain high strength heat-treatable alloys by processes which do not lend themselves to rigid control of the amount of heat which is put into the metal. Thus, while such alloys are not claimed to be fusion weldable, they can readily be resistance welded.

Heat-treatable alloys of the Mg_2Si family can, however, be welded successfully by both fusion and resistance welding methods.

A considerable amount of investigation work has been carried out in the United States on the fusion welding of those alloys which we do not consider fully weldable, and published results indicate that on re-heat-treated welded test pieces, tensile strength values of from 80–100% of those of the parent metal can be obtained. The ductility of such welds, however, is very erratic and is always considerably below that of the original metal. Furthermore, the corrosion resistance of such joints is destroyed in the vicinity of the weld. There appears to be at present only little, if any, information relating to applications of this work to actual fabrications, but its usefulness might at some time become apparent in cases in which the reduced ductility and corrosion resistance properties do not prove to be deterrent factors.

Aluminium alloys have a very narrow solidification range and a high solidification shrinkage. The former property necessitates close control of welding temperatures in order to avoid burning through and collapse of the joint: this can be offset to a large extent by the use of back-up bars and a suitable welding technique, while high solidification shrinkage can readily be allowed for by suitable jigging of the work.

In addition to metallurgical factors, certain physical properties also exert profound influences upon the weldability of a metal, and in the case of aluminium, those of oxide film, thermal and electrical conductivity, specific and latent heats, and thermal expansion are the most important.

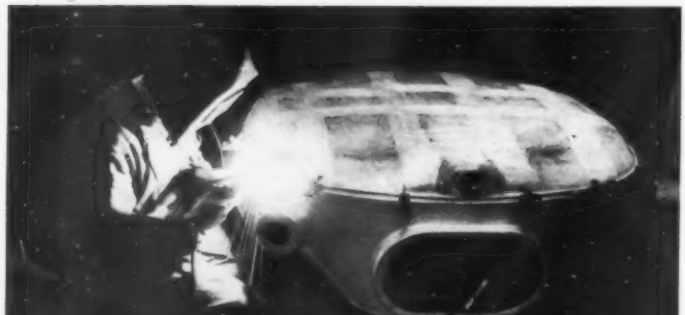
The various processes, other than mechanical ones, used for joining aluminium and its alloys, therefore, are in part the results of endeavours to minimise the effects of these metallurgical and physical characteristics, and to obtain joints as little different as possible in properties from those of the parent plate. Of these processes, those in most common use at present are: oxy-gas welding; metallic-arc welding; atomic-hydrogen welding; carbon-arc welding; argon-arc welding; inert-gas-shielded metal-arc welding; stud welding; spot welding; seam welding; flash welding; butt welding; pressure welding; brazing; soldering; and joining by adhesives.

Oxy-Gas Welding

Welding is carried out with an ordinary gas-welding torch, using as large a nozzle as practicable and suitable gas pressures to give a soft neutral flame: too high pressures tend to force the molten metal ahead of the weld pool on to unmelted metal, resulting in lack of fusion and unsound welds. A suitable welding flux is necessary in order to get rid of the oxide film; such fluxes, however, are very corrosive in nature towards aluminium, and all trace of flux residue must be removed after welding.

Powdered welding fluxes for use with aluminium take up moisture from the atmosphere very readily, rendering the dry flux first lumpy then wet. Flux which has so deteriorated is unfit for good welding, and it is important, therefore, to take particular care to keep the flux tins closed after sufficient flux for the job in hand has been taken out.

Advantages of this process include flexibility in operation; the production of welds which are dense,



Courtesy of The de Havilland Aircraft Co., Ltd.

Manual argon-arc welding of aircraft fuel tank.

free from porosity and of good appearance ; the ease with which thin materials can be welded ; and cheapness of equipment.

Disadvantages include the need for more edge preparation of the parent metal ; the need for flux removal after welding ; appreciably greater amounts of distortion ; comparatively slow rate of welding ; greater disturbance of mechanical and physical properties ; and inherent restrictions imposed on positional welding.

The mechanical properties of " as-welded " joints in strain-hardened material are of the order of the strength of the annealed parent metal, while those of " as-welded " heat-treatable alloys may vary from annealed to solution-treated strengths, depending upon the mass of the weldment, shape, joint design, etc.

Metallic-Arc Welding

This process uses an electrode in the form of a flux-coated wire of the desired alloy composition. Welding is carried out using direct current, with the electrode connected to the positive pole of the current supply. Some welding is carried out using alternating current with a superimposed high-frequency current for ionisation purposes and to give increased arc stability, but, on the whole, results from this method are not so satisfactory as those with direct current welding. Although aluminium-magnesium alloys are sometimes metallic-arc welded, the results obtained on these alloys by this process are not so successful as those obtained when welding them by certain other welding processes. Less softening of the base metal is caused by metallic-arc welding than by gas welding, but the strength values of arc welds depend on the welding currents used and the operator's skill ; the higher the current the faster the welding speed and the better the penetration.

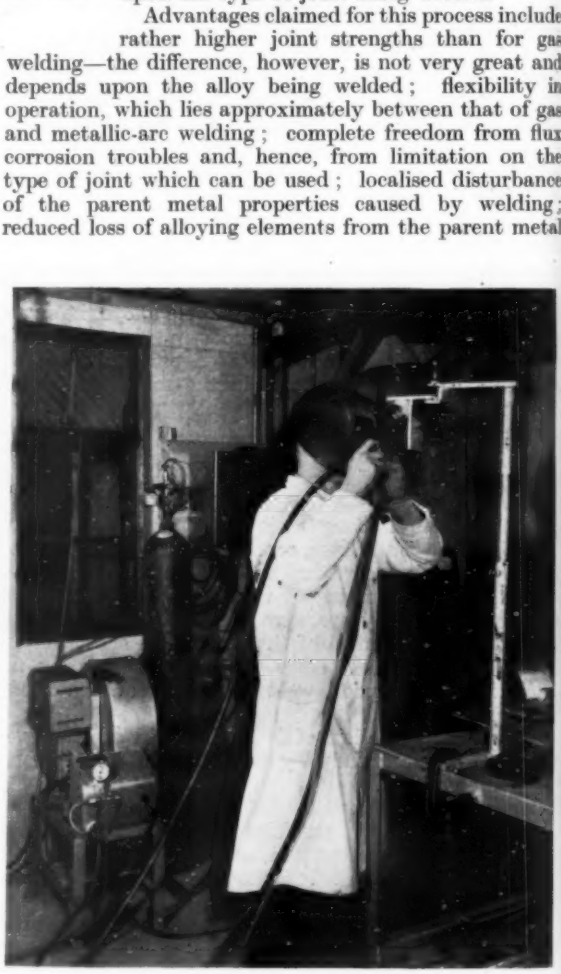
The advantages of metallic-arc welding, therefore, include minimum disturbance of mechanical properties ; reduced distortion due to concentration of the welding heat ; fast welding speed resulting in higher production rate ; lack of need for accurate edge preparation for materials up to $\frac{3}{8}$ in. or $\frac{1}{2}$ in. thickness ; and the possibility of some positional welding.

Disadvantages attributed to the process include porosity in welds and the necessity for slag removal—both failings which, however, are now being tackled by the introduction of improved electrodes and welding technique ; rougher appearance of finished welds ; limitation of the minimum thickness which can be welded, which is generally accepted to be about $\frac{1}{8}$ in. ; and higher initial cost of equipment.

Argon-Arc Welding

This process uses alternating current, the arc being struck between the base metal and a non-consumable tungsten electrode, with the electrode, arc and weld pool continuously shrouded by argon gas during the welding operation. This is a fluxless process, the aluminium oxide film being removed from the weld pool by electrical forces during welding. Welding can be carried out with or without the use of a filler wire, depending upon the type of joint being welded.

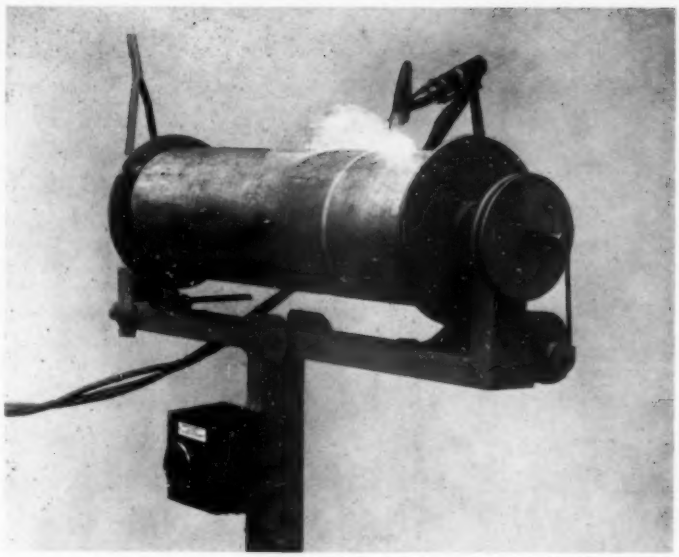
Advantages claimed for this process include rather higher joint strengths than for gas welding—the difference, however, is not very great and depends upon the alloy being welded ; flexibility in operation, which lies approximately between that of gas and metallic-arc welding ; complete freedom from flux corrosion troubles and, hence, from limitation on the type of joint which can be used ; localised disturbance of the parent metal properties caused by welding ; reduced loss of alloying elements from the parent metal



Inert-gas-shielded metal-arc welding.

during welding ; the need for only relatively simple edge preparation ; the feasibility of all positional welding ; the neat appearance of the weld beads ; reduction of distortion to a minimum ; and the ease with which the process lends itself to mechanisation.

The disadvantages include comparatively expensive capital cost for the equipment and the cost of the argon gas ; limitations on the use of the process for site work and in open shops and yards on account of draughts ; the delicate nature of parts of the equipment when subjected to rough treatment, as meted out to welding equipment in shipyards and like places ; the necessity for the use of backing bars and for accurate set-up of weldments ; limitation of accessibility of the inside of sharp corners owing to torch design ; the necessity for keeping the length of leads from the torch to the high-frequency source below 15 ft. in order to overcome dissipation of the high-frequency current ; and, finally, the adverse psychological effect that the presence of high-frequency has on some welding operators.



Courtesy of R. Y. Pickering & Co., Ltd.

Automatic argon-arc welding of light alloy tee piece.

Inert-Gas-Shielded Metal-Arc Welding

This process is a development of the argon-arc process, and is one in which an arc is struck between the work-piece and a consumable wire which is both the electrode and filler material, the wire being continuously fed through the welding nozzle and consumed in the arc, with the wire, arc and weld pool always protected by an argon gas shroud. The process uses direct current from standard D.C. generators using reversed polarity (electrode positive) connection, which is the polarity of the half cycle in which oxide removal takes place in A.C. argon-arc welding. Extremely high current densities are used with very fast wire speeds giving, in turn, fast welding speeds. In general, the process deposits weld metal across the arc gap in the form of a fine spray, the arc length being maintained by making use of the basic difference in the arc voltage caused by lengthening or shortening the arc length. The flow of argon gas ceases immediately welding stops, since there is no tungsten electrode to be prevented from oxidising as in argon-arc welding.

While the rate of flow of argon gas is considerably above that used in the tungsten-arc process, the consumable electrode welding process, due to its high deposition rate, shows considerable economies in operation over the former process.

The advantages claimed for the process are all those advantages claimed for the tungsten-arc welding, plus faster welding speeds ; greater ease in operation for all operating positions ; suitability for use in the open air ; and a saving on total welding costs in certain instances. The disadvantages include superficial porosity of the weld deposit ; limitation on minimum thickness of material which can be welded by the process ($\frac{1}{8}$ in.) ; and the necessity for specially prepared feed wire which at present makes for a costly item.

Courtesy of Metropolitan-Vickers Electrica lCo., Ltd.

Atomic-hydrogen welding torch in operation.

Atomic-Hydrogen Welding

This is another electric-arc process, but is one which is not applied to aluminium welding so frequently as the previously-mentioned electric-arc methods. In this process, a single-phase A.C. arc is struck between two adjustable tungsten electrodes held in a suitable holder. A stream of hydrogen or cracked ammonia gas is fed over the electrodes into the arc, where it is momentarily dissociated from its molecular form into the atomic state, with immediate recombination of these atoms and the liberation of intense heat just beyond the arc zone.

Courtesy of The Lincoln Electric Co., Ltd.

Carbon-arc welding.

Disadvantages attributed to the process are unwieldy equipment, offering some difficulty in operation in confined spaces; appreciable distortion on thin work; the need for the use of a flux for oxide removal, and the subsequent need for removing flux residue after welding; and its suitability for use on relatively light gauge material only. Advantages include the very hot, concentrated heat source; inherent flexibility; comparative cheapness in operation; and the ease with which it can be mechanised.

Carbon-Arc Welding

Carbon-arc welding uses a heat source supplied by striking an arc between a carbon electrode and the workpiece. Standard D.C. welding equipment is satisfactory, using straight polarity (electrode negative). This process is satisfactory for use on material from $\frac{1}{16}$ in. up to 1 in. thickness, and the quality of the weld is comparable with that made by gas welding. The process can be readily made automatic, but the use of a welding flux and filler material is necessary in either case. When the process is mechanised, it is advisable to equip the welding head with a means of supplying a stabilising A.C. field around the arc. Feed wire in coil form is preferred for automatic welding, while the flux in powder form is fed continuously to the joint at the welding point. For manual welding, metallic-arc welding electrodes, or wire thinly coated with a special carbon-arc welding flux mixed with water are used. Grooved backing plates are used where sagging of joints is possible. Carbon-arc welding offers the advantage of flexibility, but has the disadvantages of the necessity for the use of a flux, and of not being suitable for positional welding.

Stud Welding

This process is one used for attaching light alloy studs to aluminium plate and uses direct current at an open-circuit voltage of about 70, together with the necessary hand tool for holding the stud, and timing mechanism for controlling the welding cycle. Studs with special end preparations are used, together with ceramic ferrules, one for each stud driven, the purpose of these being to retain the molten metal and prevent excess expulsion of it during the welding cycle. The main advantages offered by this method of welding are a quick method of making attachments without recourse to drilling and tapping or bolting; complete absence of welding flux; speed in operation; and compactness offering good accessibility to welding in awkward positions.

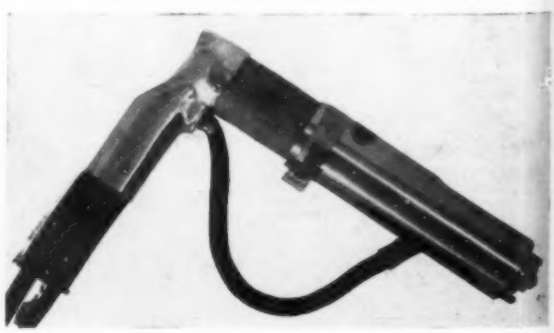
Disadvantages may be said to include the need for very high welding currents; the need for special shaping of the stud ends; the cost incurred by the necessity for using consumable ferrules; and the difficulty which some people may experience in determining the soundness or otherwise of a joint, merely by visual examination, which at the moment appears to be the only method available other than destructive testing.

Spot Welding

The design and requirements of a light-alloy spot-welding machine are markedly different from those of one designed for ferrous welding, the difference originating fundamentally from the metallurgical and physical properties of light alloys previously mentioned. Owing to the greater specific heat, lower specific resistance, and greater thermal conductivity of the light-alloy material, the power required to weld a certain thickness of light-

Courtesy of Crompton Parkinson ,Ltd., Cye-Arc Stud Welding Division.

Sectioned and etched light alloy stud welds.



Courtesy of Crompton Parkinson, Ltd., Cye-Arc Stud Welding Division.

Stud welding hand tool.

alloy sheet is approximately three times that required for spot welding mild steel of like gauge. This factor, plus the necessity for absolutely accurate control of all the welding machine variables—current, timing, and electrode pressure—has resulted in equipment, the price of which is considerably more than that necessary for ferrous welding.

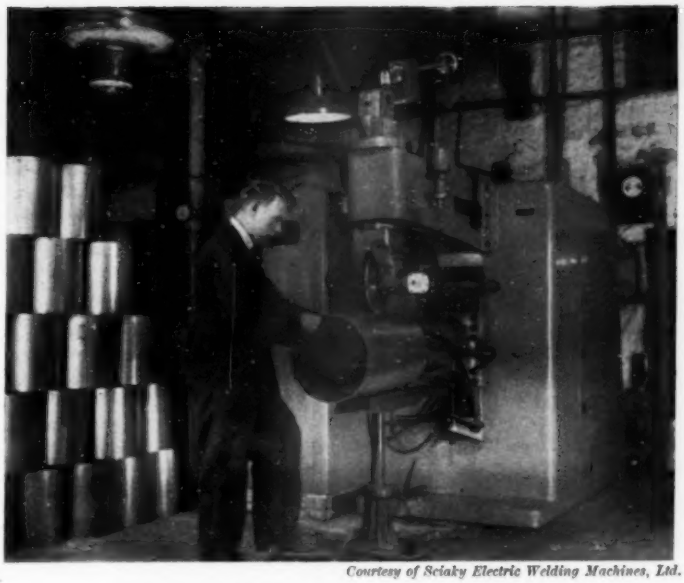
Light-alloy spot-welding machines were developed along three independent lines, producing the three present-day types of machine :—

(*a*) D.C. electro-magnetic stored energy machines ;
(*b*) D.C. condenser stored energy machines, and
(*c*) straightforward A.C. machines.

It is, however, true to say that sound spot welds of the same size have approximately equal shear strengths no matter which type of machine is used. Successful spot welding depends upon the selection of correct welding currents, times and pressures, the effects of which are profoundly influenced by electrode shape, size and material, and sheet surface conditions. Electrode tip shapes, therefore, need to be accurately maintained and fitted with adequate water cooling arrangements, while sheet surfaces to be spot welded should be suitably prepared by the use of appropriate etchants or by mechanical means.

High quality spot welding calls for close control of welds during production, since seldom is it possible to carry out extensive X-ray examination. The usual tests applied during production are those of visual inspection and the taking of mechanical tests and check tests at regular intervals as follows :

(1) on starting up ;
(2) at the end of a run with a given setting ;
(3) on re-setting the machine for a different material ;
(4) before and after changing electrodes ; and
(5) at stated intervals during production.



Courtesy of Sciaky Electric Welding Machines, Ltd.

Seam welding aluminium alloy drums.

Courtesy of Sciaky Electric Welding Machines, Ltd.

Spot welding of aluminium trunks.

There has developed a post-war tendency to use spot welding for commercial work without using the " aircraft-quality " surface preparation requirements on the material, in order to produce a cheaper application where optimum weld strength and consistency are not first requirements.

The aluminium-manganese alloy is one which is now often used for spot welding without any pre-spot-welding preparation, other than that of degreasing, the welding being carried out on machines which would prove inadequate in size for welding the same material prepared by scratch brushing or pickling.

A modern development in spot welding is the use of three-phase loading, which solves the problem of unbalanced mains loading, provides near unity power factor, imparts versatility to a machine and reduces the power demand necessary for a specific welding job.

The advantages of spot welding are a high rate of production ; cheapness in operation ; consistently strong welds ; no appreciable impairing of the properties of the metal surrounding a weld ; absence of flux ; and the possibility of the use of unskilled labour for machine operation.

The disadvantages include high initial cost of equipment ; complicated nature of equipment ; possible power installation limitations ; the necessity for scrupulous cleanliness in material preparation ; the necessity for having to prove weld soundness by destructive tests ; and the possibility of limitation on design imposed by accessibility of the machine.

Seam and Roller Spot Welding

These processes are really refined versions of ordinary spot welding, in which spot welds are made to overlap

one another to provide a water-tight seam. Roller spot welding is somewhat slower in operation than is seam welding, since, in the former process, movement of the workpiece is halted while the spot is made, whereas the job is continually moving when being seam welded. Rather more difficulty is experienced, however, in producing sound seam welds than is met with in producing sound seams by roller spot welding. The advantages and disadvantages of these processes are much akin to those of orthodox spot welding.

Flash Welding and Butt Welding

These processes have been classified together since there is considerable similarity in the set-up and method of operation of each. Both processes are carried out by passing heavy welding currents through the pieces to be joined while their ends are in contact. The welding variables of current cut-off, amount and speed of upset, rate of travel, clamping conditions and die alignment, need closer control for successful flash welding than for butt welding. The necessity for fettling flash welds is rather less than that for butt welds, since in flash welding most of the allowance for " burn off " disappears with explosive violence during the flashing period, whereas with butt welding practically all the upset allowance remains as upset in the weld and the weld vicinity after welding. The advantages and disadvantages of these two processes are very much the same as those for other resistance welding processes, i.e. the former include high rates of production by unskilled labour ; no necessity for strict control on cutting tolerance of individual members ; complete freedom from welding flux and cheap cost of individual weldments. The disadvantages are high initial cost of machines ; the necessity for fettling after welding ; and the necessity for large runs of repetition work in order to render the process economic.

Courtesy of Crittall Manufacturing Co., Ltd.

Flash welding aluminium alloy.

Aluminium Brazing

Aluminium brazing is carried out at temperatures only slightly below the melting ranges of the common aluminium alloys. The filler material flows like a solder around and into the joint, and diffusion of it into the base metal takes place, resulting in a continuous alloy structure.

The process is very simple to operate and suitably designed joints are extremely neat in appearance and often hard to detect owing to the filler metal having much the same colour as the base material. The strength of a well-made brazed joint is equivalent to that of a gas welded one, and the corrosion resistance is good, protection by painting or anodising being needed only in cases where the parent metal itself would call for it. The alloys most suitable for brazing include commercially pure aluminium ; aluminium-manganese alloy ; aluminium-silicon alloy ; aluminium-magnesium-silicon alloy (H.G.9 and H.G.10) ; and aluminium-low-copper alloys such as L.M.7 (2%) and L.M.16 (1½%). Alloys containing more than 2–3% of magnesium are difficult to braze.

Brazing filler material may be in the form of wire or thin foil, depending upon the type of assembly to be brazed and the way in which brazing is to be carried out. Special brazing sheet is also available in which the core material has an integral coating of the brazing material on one or both sides. Thus, during brazing, the brazing material on the surfaces of the assemblies melts and flows together with adjacent surfaces. Scrupulous cleanliness is necessary and the use of a special brazing flux is essential ; this flux is corrosive towards light alloys and all traces of it must be removed after brazing.

Brazed joints are classified by the methods used in applying the brazing heat, which are : torch brazing, furnace brazing and flux-dip brazing.

Torch brazing is carried out with gas-welding equipment by heating the filler wire, picking up brazing flux on the end of it and applying it to the heated job. Just below the brazing temperature, the flux melts and " wets " the joint, and with little further addition of heat the filler material melts and flows into the joint line.

Furnace brazing is carried out by applying the flux to the joint and pre-setting the brazing material in the form of shims, wire fillets or circlips, after which the assembled job is put into a furnace, the temperature of which is accurately controlled. After a short period of time, the brazing material melts, flows and effects the joint.

Flux-dip brazing makes use of a bath of molten brazing flux as the heating medium. Assembled joints, complete with pre-placed brazing material, are immersed in the bath, which both fluxes the joint and completes the braze. The operating temperature of the bath is slightly higher than the melting point of the filler material, but, of course below that of the parent metal.

After brazing by any of these methods, it is imperative that the brazed assemblies be thoroughly washed in hot and cold water to remove all trace of brazing flux residue, since if this is left in position, corrosion of the joint may result. Advantages of aluminium brazing include ease of operation in all three methods of brazing ; cheapness of the process in production (the cost of

brazing is generally less than that of either gas or metallic-arc welding); the neat finished appearance of the joint which needs little or no subsequent finishing; and the low limit to the thickness of material which can be joined by this process compared with other welding methods.

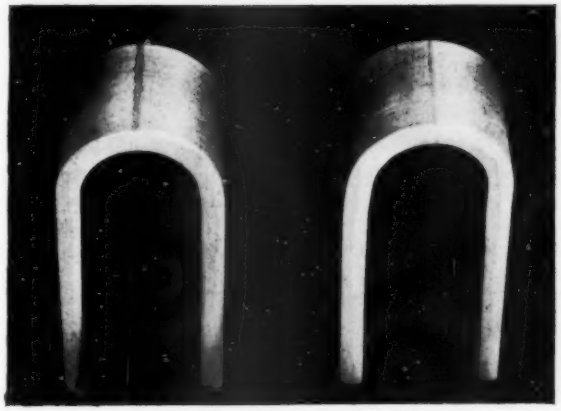
Disadvantages may be said to include the necessity for accurate set-up of joints; the need for design of weldments to be self-locking or for the use of jigs; the complete general softening of the strain-hardened materials when brazed by furnace or dip methods; the necessity for the complete removal of flux residue after brazing; and the objection raised at times to the darkening of the joint on subsequent anodising.

Aluminium Soldering

This joining process is not at present accepted as being a completely successful one, although there are several instances on record which show certain aluminium soldered joints to be giving good service. In general, the difficulty in producing a good soldered joint is a two-fold one. Firstly, the presence of the oxide film which will not respond to orthodox soldering fluxes, and secondly, the corrosion problem once a soldered joint has been obtained.

The main objection to soldering using a flux for oxide removal is that relating to their corrosive nature; there is now, however, at least one flux which is claimed to be successful in operation and non-corrosive in its after-effects, and which is finding use in stranded cable joining. Other solders rely on scraping the heated aluminium surface to break up the oxide film, the scraping being carried out under a pool of molten solder so that when particles of the film are abraded away the molten metal can alloy with the oxide-free surface which is exposed. The success of this method depends on the design of the joint as to whether or not such a process is practicable. There is, of course, no question of flux corrosion with this method of soldering. Yet another method sometimes used is that of reaction soldering, in which salts of certain metals are used. One such salt, that of zinc chloride, may be placed upon the part to be soldered and heated until the salt breaks down. At this point, the chloride ion reacts with the metal surface to form aluminium chloride which is given off as white fumes, while the metal of the salt is deposited on the cleaned aluminium surface. The method is a very messy one, however, and is apt to give rise to entrapment of considerable amounts of flux residue.

The use of compressional wave energy for the breakdown of this oxide film has been investigated during recent years, and has resulted in the development of at least one piece of equipment for which successful aluminium soldering is claimed. The process consists essentially of imparting ultrasonic agitation to the molten solder pool via a soldering bit vibrated by means of a magnetostriction transducer, the frequency of the vibrations being about 20 kilocycles. The solder is run on to the workpiece by means of the soldering bit, which is also heated by an orthodox heating element. Other soldering of this nature is carried out using a bath of molten solder which is supersonically agitated, soldering being carried out by immersion of the pieces to be soldered in the solder bath. Limitations, however, are imposed on this process at the moment, which confine its applications to very small joints which do not need appreciable volumes of molten solder to make them.



Courtesy of The British Oxygen Co., Ltd.

Flame-brazed aluminium bend test pieces.

The more important corrosion aspect is that of galvanic attack between the aluminium and certain solder metals in the presence of moisture and, for this reason, some form of protection in the form of paint or varnish should be afforded to the joint where possible.

Pressure Welding

Pressure welding is based on the fact that if two perfectly clean and oxide-free metal surfaces are placed in absolute contact, crystal growth will take place across the plane of contact due to a transition of atoms from crystal lattices of one surface to preferentially positioned lattices on the other. Such ideal conditions, however, become extremely difficult to achieve, but commercial approach is made to the subject by thoroughly cleaning the surfaces to be welded and applying varying amounts of heat and pressure. In general, although the welding pressure depends to some extent on the alloy being welded, it might be said that the higher the joining temperature the lower the joining pressure necessary.

The all-important requirement for successful pressure welding is absolute cleanliness. Surface preparation of the material involves scratch brushing or pickling followed by scratch brushing. The scratch brushing is carried out by power-driven rotary wire brushes of thin gauge wire, and with a peripheral speed of 2,000–3,000 ft./min.

The material surface must on no account be handled after preparation, since oil, grease or perspiration from the hands would contaminate the cleaned surface and prevent welding. Where heating of the material is necessary, heat is applied to the workpiece through heated welding dies and not by the application of a naked flame to the surface of the material.

The strength of a pressure weld compares very favourably with the strength of joints produced by other welding methods. Joint design, however, plays a very important part in determining the strength and, by suitable arrangement of welds, joint strengths equal to the parent metal strength can readily be obtained.

Pressure welding with heated dies is more suitable for use where long lengths of joints are incorporated in compact weldments; in this case the dies are the shape

of the finished weld. Cold pressure welding, however, lends itself more readily to the making of joints which consist of one or more welds of comparatively short length, or where long welds are made progressively, as when using rollers for welding dies.

Advantages with both processes are that no flux is necessary, hence there exists no corrosion problem; and that the processes can be operated by unskilled labour. Special advantages for cold pressure welding include extreme simplicity in equipment necessary; low capital outlay for tools, and practically no upkeep costs, hence a low cost of welding per weldment; versatility of application from spot to seam welding; and the absence of disturbance of base metal heat treatment. The main disadvantages of the method are the appreciable depth of indentation caused by the welding dies; and the meticulous care necessary in handling the stock once it has been cleaned for welding. Further disadvantages in the case of pressure welding with heat are the necessity for bulky and expensive presses and heated platens; and the high cost of dies which might result from complicated design of weldments.

Adhesives

The use of adhesives for joining metal to metal and metal to other materials is a comparatively new one and opens up a considerable field. Joining is carried out by means of a bonding medium, which may be based on rubber, polyvinyl acetates or synthetic resins. Bonding media may be either thermo-setting or thermo-plastic: the former type undergoes an irreversible chemical change when cured by means of heat, whereas the latter can be softened and re-softened by the repeated application of heat, providing the temperature is not sufficient to cause deterioration or chemical decomposition of the bonding material.

Surface preparation usually entails absolute cleanliness, incorporating some form of chemical pickling which may or may not include anodising as a pickling process. Generally speaking, the rubber base bonding media are thermo-plastic and give lower shear strengths than the synthetic resins, which need higher curing temperatures and pressures, resulting in thermo-setting bonds.

Joint design should always be such as to offer large areas of contact and should be positioned to be stressed in shear. Typical joint shear strengths vary from 1,000 lb./sq. in. for bonding rubber to metal, with failure occurring in the rubber, up to 5,000 lb./sq. in. when bonding aluminium to aluminium and tested at atmospheric temperatures. It might be of interest here to mention that light-alloy bonding is now being used for applications ranging from the bonding of rubber to metal brackets for vibration absorbing mountings, to the attachment of brake shoe and clutch plate linings for motor cars, 'buses and coaches, and from the bonding of plywood veneer to aluminium sheets, for use in the aircraft and furniture industries, to the joining of metal to glass and metal to ceramics for use in the electrical industry.

Advantages of the process are an extremely wide field of application with no restriction on the types of metal which can be bonded; the ability to produce accurately sized jobs of neat appearance; absolute passivity between bond and base metal, with almost complete corrosion resistance of the bond; convenience of the resin-curing temperature coinciding with the precipitation-treatment temperature of the double-heat-treatable light alloys; the flexibility inherent in operating the process; and the possibility of using unskilled labour for operation.

Disadvantages include the comparatively slow rate of production; the necessity for complete degreasing and pickling; and the need for heavy press or autoclave equipment when fabricating large assemblies.

Conclusion

It is hoped that sufficient has been set forth in this article about each process to show designers and engineers that there are several satisfactory joining methods available for use with aluminium and with these to hand, the joining of light alloys is not nearly the formidable problem which many people still imagine it to be.

Spheroidal Graphite Cast Iron Patent

THE Mond Nickel Company's British Patent No. 630,070, covering the production of spheroidal graphite cast iron by the magnesium process, has now been granted. This grant is the culmination of long proceedings before the Patent Office and the Patents Appeal Tribunal. The process provides a range of cast irons with double the strength of all previous known types and eliminates the brittleness normally associated with iron castings. These irons are proving of the greatest possible importance to designers in all branches of engineering.

The application for this patent was made in March, 1947, and in May, 1948, the first public disclosure of the process was made simultaneously in Great Britain and the U.S.A. In October, 1949, the Application was accepted by the British Patent Office, and published. Opposition to grant of the patent was lodged by The Mechanite Metal Corporation on the grounds that the invention had been disclosed in certain prior publications, and that the nature of the invention and the manner in which it is to be performed were not sufficiently and fairly described in the specification.

In June, 1952, after protracted proceedings, the Patent Office gave its decision agreeing to seal the patent. Appeal against the decision was made to the Patents Appeal Tribunal and the hearing before this Tribunal took place on 10th–12th November, 1952, when Mr. Justice Lloyd-Jacob, directed that the patent should be granted. This final decision clarifying the Patent position will be particularly welcome to the numerous licensees of The Mond Nickel Company who are actively engaged in the manufacture of spheroidal graphite cast iron by the magnesium process. Similarly for engineers it will remove all doubts about the sources of supply of this important and valuable material.

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WE are advised that the complete selling organisation and manufacturing programme in this country of Poldi Steel Co. (England) Ltd., have been taken over by Poldi (England) Successors Ltd. The varied activities previously carried on will be continued, and the same range of high grade special tool steels will be manufactured and available. The services of the complete staff and workers have been retained, including all technical personnel and district representatives, most of whom have had many years service with the former company.

New and Revised British Standards

PACKAGING CODE. (B.S. 1133 SECTION 6 : 1953). PRICE 10s. 6d.

During the war most manufacturers of engineering equipment and spares were required to protect them against corrosion during transportation, in many instances overseas, as well as during storage, and B.S.I. published Section 3 of B.S. 1133, "Packaging Code" to provide assistance at that time. Some firms have continued to apply the temporary corrosion preventatives to ordinary commercial goods, but many abandoned this procedure after the war, not recognising that the need still remained to ensure that equipment remains in a good state from the time of manufacture to usage.

The disappointment and frustration engendered when goods received overseas have rusted in transit can easily be imagined, and yet there is a considerable failure to safeguard engineering equipment exported. Perhaps because many items, particularly mass-produced parts, are used relatively quickly when not exported, there has been a more persistent failure on the part of some manufacturers to realise the considerable deterioration that can occur during transit and during storage in this country. Goods in wagons or on lorries are often not protected against rain or they are put into contact with damp wood ; this is mainly a packaging problem, but corrosion prevention is also necessary. In storage it is often impossible to provide good conditions ; industrial atmospheres are usually corrosive, unheated stores are common, large articles and equipments often have to be stored outside, spare parts may have to be kept for several years before they are wanted, and so on. Corrosion preventives that can easily be removed when an article is fitted (the so-called "temporary corrosion preventives") are widely used in some works and are freely available from a considerable number of manufacturers. What is required is a wider recognition of the need for them, the setting up of standards of performance, and guidance on their suitability for particular exposure conditions and types of articles, on the supplementary wrapping and packaging that individual materials require, and on relative costs. The British Standards Institution has recently issued Section 6 of the Packaging Code B.S. 1133 to provide this information.

This Section 6 of B.S. 1133 is an adaptation of the war-time Section 3 to ordinary commercial practice. Whereas the former edition referred extensively to Government Department specifications, performance specifications for the temporary corrosion preventives have been formulated in the present edition. The general scope remains broadly the same as before : not only are temporary corrosion preventives and their uses described in detail, but the essential preliminary conditions are catered for by an extensive section on cleaning (covering all the well-established methods of dealing with oil, grease and dirt and including the removal of rust and scale) and a short section on drying. The document has been carefully prepared in order that it shall serve the dual purposes of a directly readable handbook on the subject and a reference book. It will meet the needs of technical people, but has been prepared also with the ordinary packer as a reader in mind.

GREEN PROTECTIVE SPECTACLES AND SCREENS FOR STEELWORKS OPERATIVES (B.S.1729 : 1952) PRICE 2s. 6d.

THIS British Standard specifies protective spectacles and screens suitable for use by steelworks operatives, with a view to providing comfortable vision and protection against possible injury to the eyes from harmful radiation. The standard provides also for the colour matching of pairs of lenses so that broken glasses can be replaced without affecting the wearer's ability to judge furnace conditions.

Eye-protection filters, either as lenses or as shields, are necessary for viewing industrial operations in which radiation of high intensity is emitted ; for example, welding, the collection of molten glass, and steel making and working. This radiation is commonly divided into four categories : infra-red, light, ultra-violet and total heat. An important purpose of the filter is to protect the eyes of the wearer against injury from the infra-red and ultra-violet radiation emitted. The disease known as cataract is produced by long exposure of the unprotected eyes to infra-red radiation, such as is given off by molten glass or red-hot metal. Exposure of the eyes to ultra-violet radiation may cause the painful condition known as "arc-eyes" or "eye-flash."

The filters commonly used by those engaged in steel melting and working have been made of cobalt blue glass which, by virtue of its blue and red transmission characteristic, aids visual assessment of temperature. Little protection against infra-red radiation is given, however, because of the relatively high transmission factor of cobalt blue glass in the near infra-red part of the spectrum. Furthermore, in manufacture it is difficult to control the transmission factor of this blue glass and a melter whose protective spectacles are broken finds it difficult to match them.

The particular advantages of the green glass may be summarised as follows :—

1. The green glasses protect wearers against harmful infra-red radiation while the blue filters do not.
2. The green glasses are more comfortable in use than the blue glasses because of the lack of chromatic aberration.
3. The green glasses can be replaced by a pair from stock without affecting the wearer's judgment of furnace conditions.

FLEXIBLE STEEL CONDUIT AND ADAPTORS FOR THE PROTECTION OF ELECTRIC CABLE (B.S.731 PART 1 : 1952.) PRICE 2s. 6d.

THIS British Standard forms part of the revision of B.S.731, "Flexible steel conduit for cable protection and flexible steel tubing to enclose flexible drives," which was issued in 1937. Since flexible steel conduit for electric cable protection has become dissociated from flexible steel tubing to enclose flexible drives, this standard has been given a new B.S. number ; the revision of the part of B.S.731 relating to flexible steel tubing to enclose flexible drives will form the subject of a separate British Standard to be published later.

This standard provides for three types of flexible steel conduit suitable for insulated cables—unpacked, asbestos packed and rubber packed, and for two types of adaptors—clamp type and solid type. In addition to standardising dimensions, it specifies mechanical requirements and tests for the finished conduit, and prescribes suitable qualities of materials for use in the manufacture of flexible steel conduit and adaptors for cable protection.

REELS FOR COVERED, SOLID, ROUND WINDING WIRE FOR ELECTRICAL PURPOSES. (B.S. 1489 : 1952).

REELS AND WOODEN DRUMS FOR BARE WIRE, STANDARD CONDUCTORS AND TROLLEY WIRE FOR USE IN THE UNITED KINGDOM. (Ref. : P.D.1472 Amendment No. 1 to B.S. 1559).

PRECISION REELS FOR BARE AND OXIDISED RESISTANCE WIRES (0·0005–0·0048 in. DIAMETER INCLUSIVE). (B.S.1888 : 1952).

PRICE : B.S.1489 AND B.S.1888, 2s. 6d. EACH.

Four years ago when the British Standard for reels for covered winding wires was published, it was thought that it would be a long time before it could be fully adopted in view of the alterations in machinery, etc., that would be required. In practice however, the standard has proved so successful that it is now possible still further to reduce the range of sizes of reels and a revision of B.S.1489, "Reels for covered, solid, round winding wires for electrical purposes," has now been issued. In the new standard the recommended reels for different gauges of wire have been adjusted in the light of experience, a system of reference numbers has been introduced. Marking requirements have been added and other modifications made. These modifications to B.S.1489 have made it necessary to make some adjustment to B.S.1559, "Reels and wooden drums for bare wire, stranded conductors and trolley wire for use in the United Kingdom," and an amendment slip has been issued which is available gratis.

Manufacturers of certain radio and electronic components have found difficulty in de-reeling very fine resistance wires and it has been shown that unless reels for these wires are made to precision limits, the wire stretches, giving rise to inaccuracies in the manufactured component. Moreover, accurate dimensional standardisation of these reels is an important factor in obtaining efficient service from automatic winding machines. To meet this need, the British Standards Institution has also published B.S.1888, "Precision reels for bare and oxidised resistance wires (0·0005–0·0048 in. diameter inclusive)."

Copies of these standards may be obtained from the British Standards Institution, Sales Branch, 24, Victoria Street, London, S.W.1.

The Finishing of Aluminium and Its Alloys

Continued from page 72.

from the most delicate pastel to the fullest rich tones. It can, therefore, be readily seen that the sulphuric acid process is the one to be most generally recommended for colour anodising ; on the other hand, for certain applications the chromic film is of considerable value, especially where the final results are required to match painted or lacquered surfaces exactly.

For the process of dyeing anodic films, standard dyestuffs are used, and are diluted with water to obtain the exact shade required. They can be used either hot or cold, according to the final effects desired. After dyeing it is essential that the film should be sealed, this operation taking place during dyeing when the hot dye bath is used or, subsequently, when dyeing is carried out cold, sealing may be effected by boiling in water or heating in a steam bath after dyeing. Variations in intensity of colour are obtained by varying the concentration of the dye solution, by altering the time of immersion, or by modifying the thickness of the anodic coating.

Hard Surface Finishes

In recent years, increased attention has been devoted to the hard surfacing of aluminium—one process for which is hard chromium plating—and a stage has now been reached where important engineering components can be treated with chromium with expectations of consistent reliable coatings being produced. Direct plating processes are preferred, such as those that make use of acid metal chlorides or organic acids. For this process, alloy composition is of some influence, and casting alloys containing copper are preferred, although aluminium silicon alloys have also been successfully treated. A process based on the direct application of chromium on aluminium is claimed to be applicable to most alloys, but magnesium contents of 7% and upwards are not favoured.

The thickness of the chromium film should not be less than 0·001 in. and for most applications should be thicker. It has been stated that 0·001 in. thickness of chromium is sufficient to prevent pick-up on screw threads of such parts as petrol tank fillers ; but thicknesses up to 0·022 in. have been used where very heavy loading and wear is expected. It is normal practice to apply a coating slightly above the required thickness, and to grind or hone back to the actual dimensions required. As porosity in castings naturally leads to plating difficulties, gravity die castings are preferred wherever possible.

Recent developments in this country and in the U.S.A. have perfected the production of hard anodic films up to 0·010 in. thick. The British treatment can be applied to alloys with either high copper or high silicon content, but it so far appears that the American process cannot be used on aluminium alloys containing more than 5% copper and some doubt exists as to whether 12% silicon alloys can be processed. The films in both cases are normally of slate-grey colour, but with variations in the alloys these may, on occasions, be slightly brown. Preliminary investigations indicate that this sytem of anodising produces an exceedingly hard surface film which has a very high resistance to abrasion.

One successful application is the hard-anodising of the channels in aluminium alloy castings used in a metal spray pistol, the treated metal being very resistant to the abrasive action of airborne metal powders. From tests already made, it would appear that these anodic films stand up very well to wear, corrosion, and thermal shock, but it is only by experience gained over many years that the full advantages can be shown.

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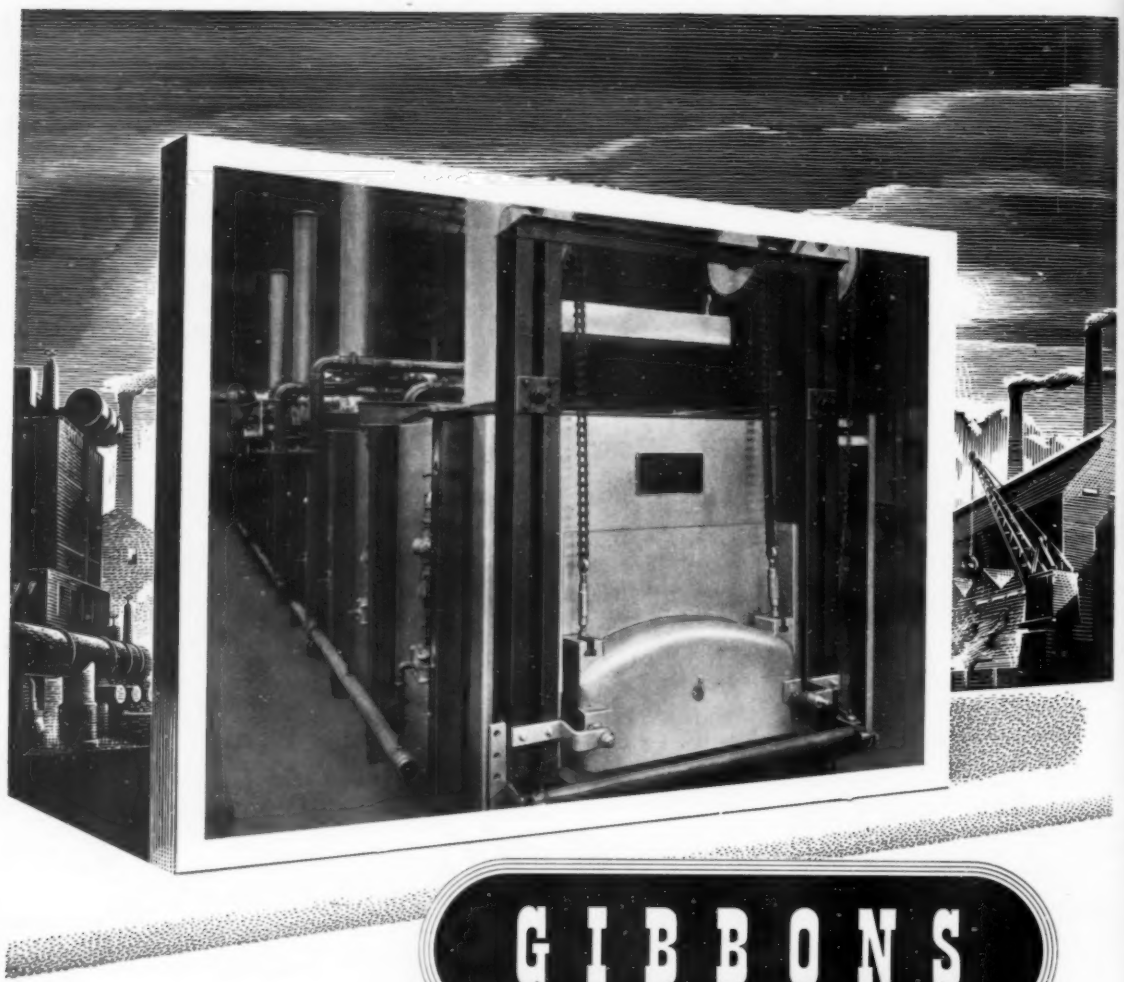

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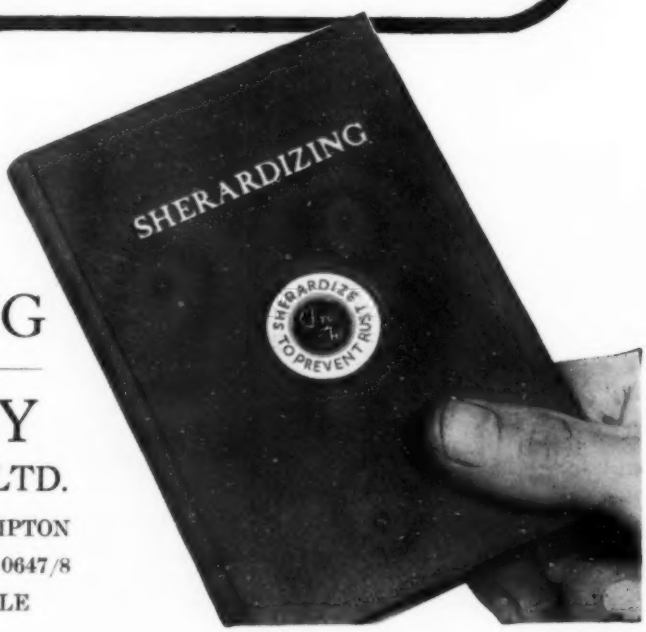

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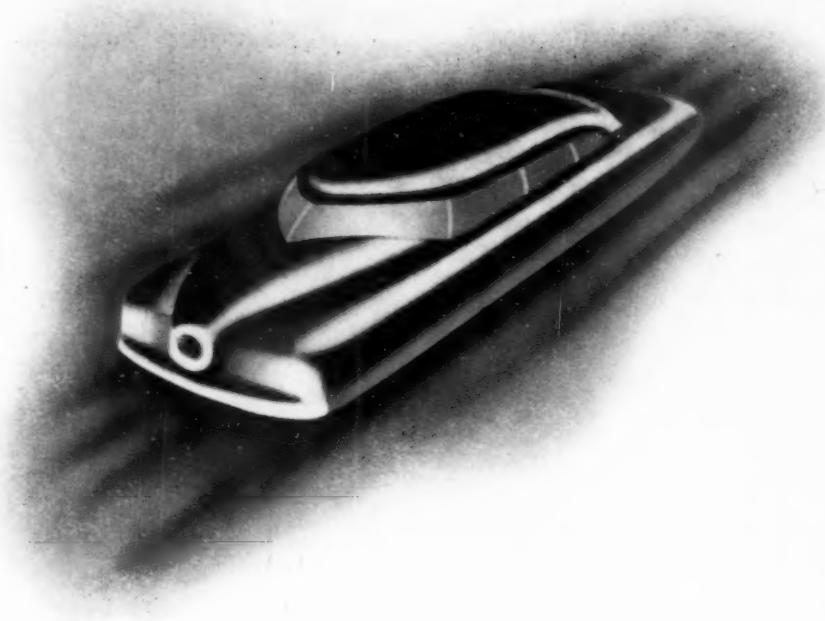

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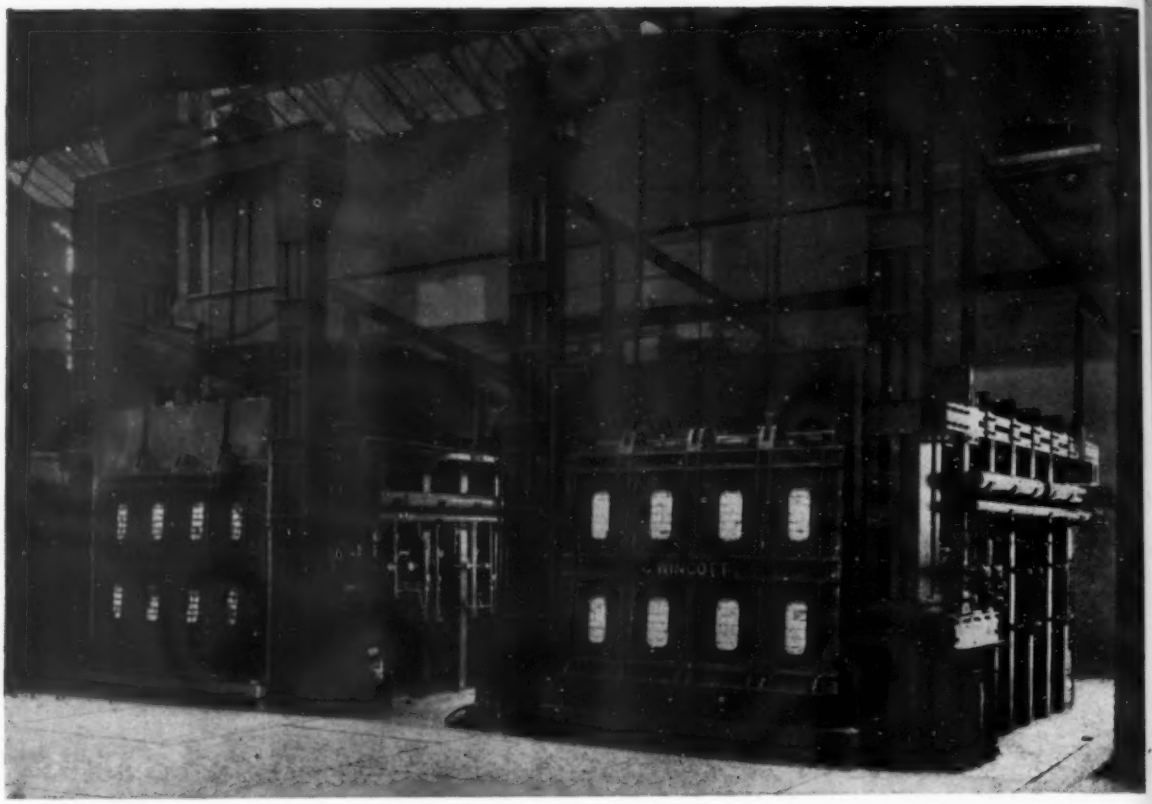

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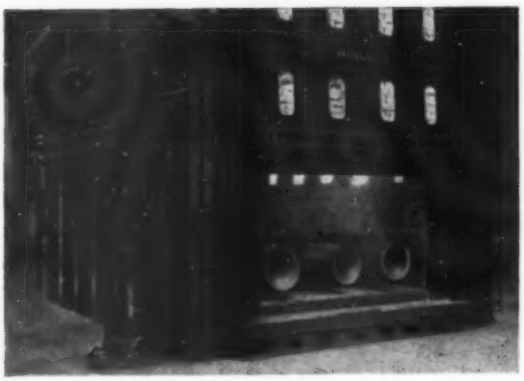

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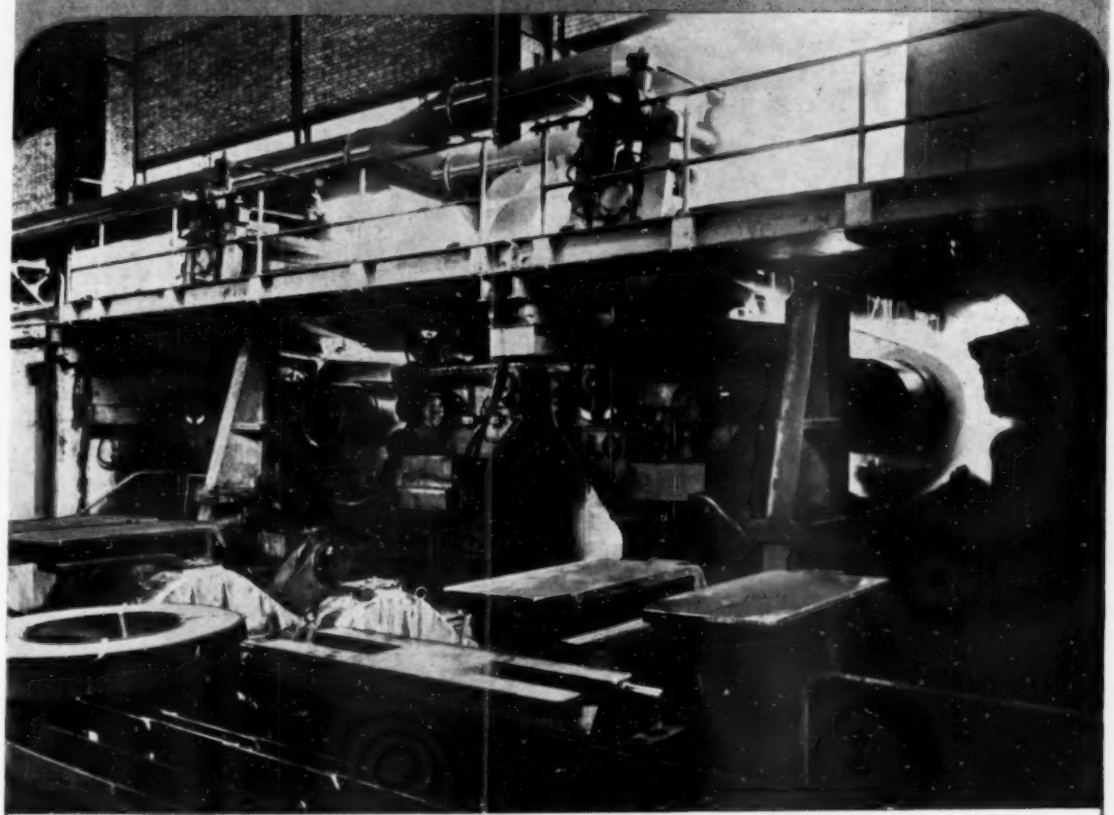

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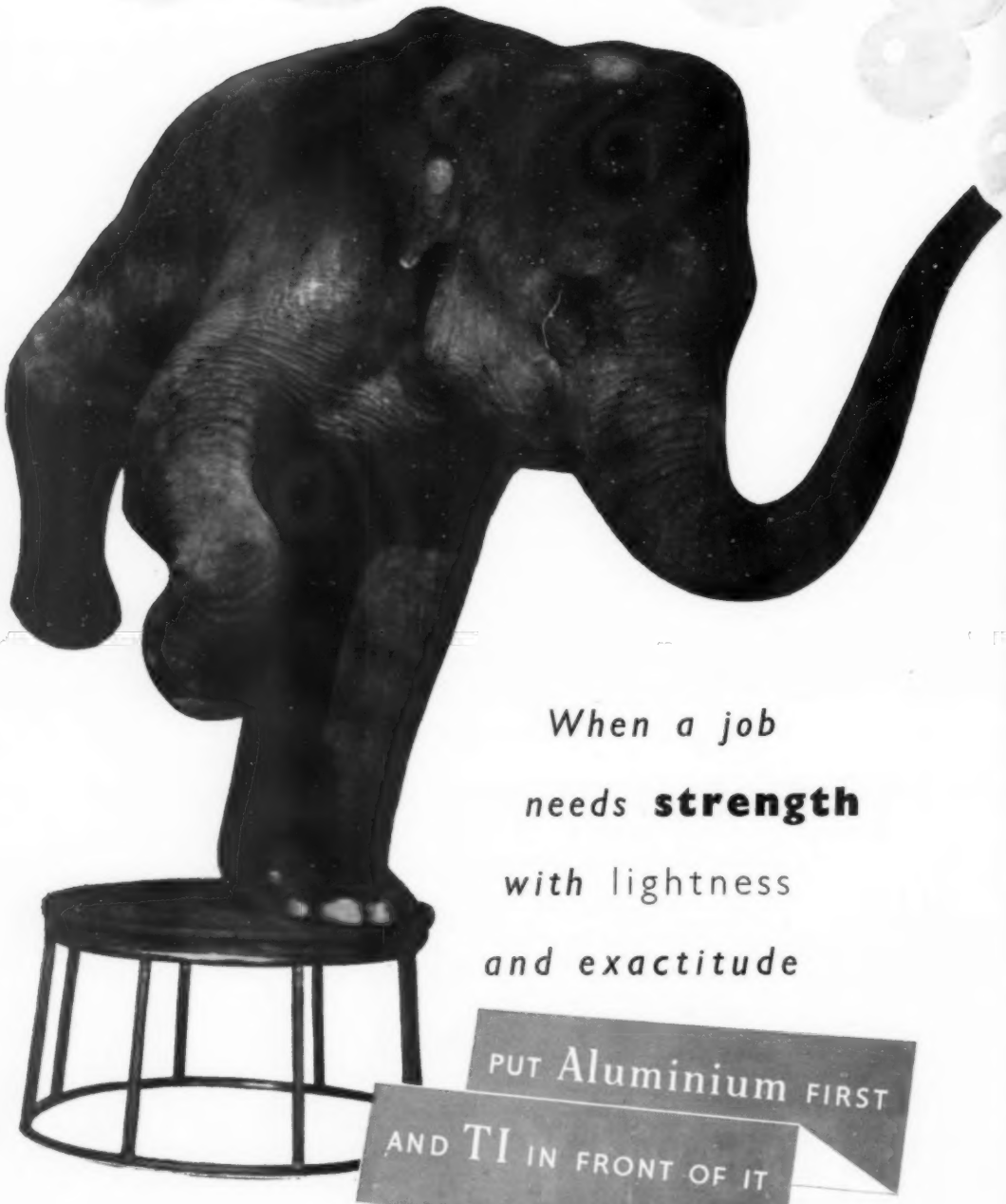

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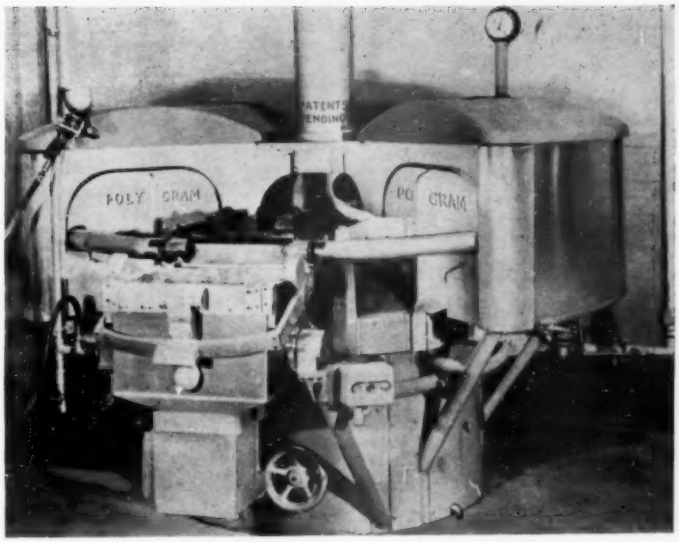
Mechanised Shell Moulding

New Machine Aids Consistency and Increases Output



General view of Polygram Automatic Shell Moulding Machine Mark IV.

THE essentials of the shell moulding process are now fairly well known. Basically, it consists in investing a heated metal pattern plate with a mixture of sand and phenolic resin. The heat of the plate melts the resin in the surface layer of the mixture and causes a "shell" to form over the surface of the pattern plate. This shell follows the desired profile very closely and, after curing, the shell can be stripped from the plate and used instead of the conventional sand mould, which may well weigh 20 times as much as the $\frac{1}{4}$ in. thick sand shell.

The Basic Process

The actual operations in this process can be summarised as :—

(1) Covering the surface of the pattern with a stripping agent so that the shell does not stick to the pattern ;
(2) Investing the plate with the resin/sand mixture ;
(3) Inverting the plate so that the surplus mixture is removed by gravity for use during subsequent investments ;
(4) Curing of the shell, which should be left in contact with the pattern plate during this operation to ensure close accuracy ; and
(5) Ejecting the cured shell from the plate.

These operations have, in the past, been carried out by hand, but they are particularly amenable to mechanisation. Such mechanisation not only greatly reduces the man-hours required to produce a given number of moulds, but also standardises many of the variables so that a product of consistently higher quality is obtained. Specially designed for this process is the Polygram Automatic Shell Moulding Machine Mark IV, which is illustrated here. This model has a manual rollover of the counter-balanced investment bin, but other designs are available with different bin sizes to suit different pattern plates, and the Mark V has a fully-automatic rollover mechanism.

The Mark IV machine, which has an overall diameter of 6 ft. 6 in., and a height to the crown of the oven dome of 4 ft. 3 in., carries four metal pattern plates, spaced equidistantly on a rotary indexing frame. At any time three of the plates are in the gas-fired oven and the fourth is at the moulding station, at which is located an investment bin containing a $7\frac{1}{2}\%$ resin/sand mixture. After spraying with stripper, the hot pattern plate and its carrier are swung over and locked in position on the open end of the counterbalanced investment bin. The bin is rolled over through 180°, so that the resin/sand mixture falls onto the pattern plate, and pressure is applied by means of an air cylinder to press the investment tightly against the pattern plate in order to ensure a better impression. After a suitable time interval, the bin is returned to its original position, and the pattern plate, with its shell or "biscuit," is swung back onto the indexing frame, which carries it into the first of the three heating stations in the oven. At the same time, the next pattern plate emerges from the oven with its cured shell and comes to rest at the investment station, where the ejector mechanism lifts it from the mould for removal by the operator, the pattern plate being sprayed and invested again.

Speed of Working

The complete cycle of investing and baking takes about two minutes, during which time four half moulds are produced, so that the output of the machine is 60 complete moulds per hour. The cycle is normally sufficiently long for a deft operator to have a pause of a few seconds before having to proceed with the next plate, and this largely offsets fatigue, thus enabling a figure very close to the nominal output of one mould per minute to be kept up over the complete working day. The cycle time is controlled within limits of $\pm$ 20% by means of a variable speed handwheel at the base of the machine. In the automatic rollover machine, the time of investment can still be set by the operator, in order to give the necessary flexibility when using four widely different pattern plates on the machine at the same time.

The oven of the machine may be started by a time

Pattern plate sprayed with stripper and ready for investment.

The pattern plate has been rolled over the mouth of the investment bin and clamped.

switch before the workers arrive in the morning, and it is then only a matter of dropping the required pattern plates in their carriers and running the machine for about 8–10 complete cycles before it is ready for operation. Pattern plates can be changed without slowing up the machine and, if they have been pre-heated, the plates can be put into immediate operation, with the loss of only one half mould for each plate.

An important feature is that all the mains supplies can be brought up under the base of the machine so as to have a clear floor space all the way round. This renders sweeping and maintenance extremely easy, since there are no pipes to obstruct or harbour dirt. This cleanliness is greatly assisted by the complete absence of any deposition of the mixture on to the floor when the bin is inverted.

Due to the design, the mechanism is readily accessible. The specially designed gear box, together with a robust and accurately manufactured indexing mechanism, are such that the machine can operate successfully in the most arduous foundry conditions. The ejector system is the outcome of many experiments which have resulted in a most successful positive ejection. These features mean that the only attention which should be required is a brief maintenance check-over each week, and a slightly more extensive one at longer intervals.

Gas Consumption

Gas consumption has been kept to a minimum by the careful design of the burners and lagging of the oven, as well as by the fitting of a gas governor. Consumption is at the rate of perhaps 200 cu. ft. in the first 20 minutes, while the oven is reaching curing temperature, and then at the rate of less than 150 cu. ft./hour for the rest of the day. The action of the governor is such that the temperature of the oven is rapidly returned to the desired point after the indexing mechanism brings in colder materials. After these few seconds, the intensity of the gas flow is rapidly lowered, since a steady temperature is maintained inside the well lagged walls.

The machine is driven by a 1 h.p. screen-protected squirrel-cage induction motor, which is protected from mechanical overload by a safety clutch on the main shaft drive. Should any mechanical defect occur, this clutch will slip before any damage is done, and on the obstruction being removed, the machine will again function perfectly. A further safety device is incorporated, whereby, unless the pattern plate is returned to its carrier before the indexing motion starts, the motor will automatically cut out.

To the advantages of consistency of moulds and hence of castings made from them, may be added the relatively low cost of the machine—it is claimed that it will pay for itself in less than a year—and the fact that it can be operated by completely unskilled labour, the actual work involved being clean and not too arduous—important factors in the recruitment of labour.

Ford Breaks Pig Iron Record

THE Ford blast furnace, affectionately known as "Josephine" by workers at the Ford Works, Dagenham, has broken a national record by exceeding a figure of 1,553,766 tons of iron produced without relining. This has been accomplished in only 8 years 3 months—nearly 2 years better than the previous record. The achievement is all the more remarkable for the Ford furnace has been producing iron of a high silicon content, as opposed to basic iron on which the old record was established, and has done so using less coke per ton of iron produced.

"Josephine" which is the only blast furnace in the South of England and only 12 miles from London, began operating in 1934 and in 19 years has produced well over 3,000,000 tons of high quality iron. Mr. T. L. Nuttall, O.B.E., Manager of the Manufacturing Services Division of Ford Motor Co. Ltd., recently congratulated his men when they passed their own previous record (at the time another national record) set up in 1944. Now further credit is due to the team.

Industrial High Frequency Equipment

WE are advised by Wickman Ltd., that their interests in industrial high frequency heating equipment, previously operated as a separate subsidiary business under the name of Applied High Frequency Ltd., are now run directly as a Division of the Company under the title of Wickman Ltd., Applied High Frequency Division. The address of the new Division will be the same as that of Applied High Frequency Ltd., namely, Actare Works, Goldhawk Road, London, W.12.

NEWS AND ANNOUNCEMENTS

Extra-Mural Lecture Courses

A programme of special courses has been arranged by the Department of Coal Gas and Fuel Industries with Metallurgy of the University of Leeds, in association with the Department of Adult Education and Extra-Mural Studies. Brief particulars of a number of these lecture courses are given below.

Disposal of Waste Liquors Produced in Gas Works and Coke Oven Plants.—Two lectures on this subject will be given by Dr. W. H. Blackburn, Research Chemist to the Joint Research Committee of the Gas Council and the University of Leeds, at 2-0 p.m. and 3-30 p.m. on Monday, March 9th. Fee £1–0–0.

Refractory Materials.—The four lectures to be given by Mr. T. R. Lynam, General Manager, the Oughtibridge Silica Firebrick Co., Ltd., on Tuesdays, March 10th and 17th at 5-0 p.m. and 6-30 p.m., will deal with the manufacture, constitutions and applications of silica bricks and basic refractories. Fee £1–10–0.

Metallurgy.—Dr. F. D. Richardson, Director of the Nuffield Research Group in Extraction Metallurgy, Royal School of Mines, will give two lectures on the physical chemistry of molten slags and mattes at 2-30 p.m. and 4-30 p.m. on Thursday, February 26th. Fee £1–0–0.

Intending students are requested to send their names as soon as possible to The Secretary, Department of Adult Education and Extra-Mural Studies, The University, Leeds, 2, specifying at the same time which course or courses they wish to attend. Other enquiries regarding the courses should be addressed to the Head of the Department of Coal Gas and Fuel Industries with Metallurgy.

Brittle Fracture Conference

THE West of Scotland Iron and Steel Institute has arranged a One-Day Conference on Brittle Fracture in Steel to be held at 39, Elmbank Crescent, Glasgow, on Friday, 15th May, 1953. Papers have already been promised by the following: MR. W. BARR (U.K.); DR. S. L. HOYT (U.S.A.); MR. N. G. LEIDE (Sweden); MR. P. MATTON-SJÖBERG (Sweden); MR. T. S. ROBERTSON (U.K.); PROF.-IR. W. SOETÉ (Belgium); DR. C. F. TIPPER (U.K.); and DR. A. A. WELLS (U.K.).

Arrangements are in hand and a more detailed announcement will be made shortly. In the meantime those interested in attending the Conference are invited to send their names and addresses to: The Secretary, West of Scotland Iron and Steel Institute, 39, Elmbank Crescent, Glasgow, C.2, so that they may receive individual notification of the final arrangements.

The Institute of Fuel

Melchett Medal for 1953

THE Council of the Institute of Fuel have unanimously agreed to award the Melchett Medal for 1953 to Dr. Harold Hartley, C.B.E., in recognition of his high scientific attainments in the development of domestic heating appliances coupled with the administrative skill with which he has guided a great industrial organisation devoted to the practical efficient use of fuel.

Dr. Hartley is Chairman of Radiation, Ltd., manufacturers of heating and cooking appliances for domestic, commercial and industrial purposes. He joined the Company as Head of the Research Department in 1919, and was elected to the board as Technical Director in 1938. In 1948, he became Deputy Chairman, and succeeded to the Chairmanship in 1949.

Besides serving as President of The Institution of Gas Engineers (1947-48), Dr. Hartley has been Chairman of the Council of the British Cast Iron Research Association and, in 1945–47, President of that body. He is President of the Institute of Vitreous Enamellers, and is also one of the D.S.I.R. Visitors to the British Coal Utilisation Research Association. Dr. Hartley was awarded the C.B.E. in the 1952 New Year Honours. He has been a Member of The Institute of Fuel since 1944 and was elected a Fellow in 1948.

International Congress on Electro-Heating

ON two occasions in the past, highly successful international congresses have been held to consider the advances that have been made in all forms of electrical process heating in the various European countries taking part. The Third International Congress on Electro-Heating has been arranged for May of this year, this time in Paris, under the auspices of the Comité Français d'Electrothermie.

The Congress will be open to all interested, whatever their nationality, either as individuals or organised groups. Applications for enrolment should be sent to: Monsieur le Secrétaire du III^{e} Congrés International d'Electrothermie, 2 Rue Henri-Rochefort Paris (17^{e}), from whom prospectus and application forms can be obtained.

U.S. Steel Strip Contract Secured

THE UNITED STEEL COMPANIES LTD., announce that the Samuel Fox Branch, Stocksbridge, has secured an important contract for the supply of razor blade strip to Messrs. Gillette Industries in the United States. The initial contract calls for the supply of 45 tons per month for six months, and the total value of the order will be £96,600 or $270,000. It is interesting to note that Samuel Fox have become the sole suppliers of razor blade strip to Messrs. Gillette Industries Ltd. in the United Kingdom, and by so doing have secured trade previously placed with Sweden before World War II. The latest contract means that Samuel Fox steel will be used for some Gillette blades the whole world over.

Arc Furnace Agreement

THE Electric Furnace Co., Ltd., has recently concluded an agreement with Swindell-Dressler Corporation of Pittsburgh for close collaboration between the two companies, especially with regard to the manufacture and supply of large arc furnaces of up to 100 tons capacity, both for this country and European and Empire countries. In view of the changing situation with regard to dollars available for purchase of equipment from

the U.S.A., this agreement should prove of value, in so far as it will enable the company to offer proved American designs of furnaces, based on the large number of equipments installed in the U.S.A., manufactured and supplied by British engineering capacity. An exchange of technical information on both small and large arc furnaces has been arranged, and a satisfactory basis for the supply of all drawings and information to enable furnaces larger than hitherto built in this country has been agreed.

Two Day Conference at Birmingham

THIS year, the Department of Industrial Metallurgy, University of Birmingham, is holding its annual two-day Conference on Monday and Tuesday, March 16th and 17th, 1953. The subjects will be "The Deep Drawing of Metals" on March 16th and "Continuous Casting of Ingots" on March 17th. Full details of the programme may be obtained from the Secretary, Department of Industrial Metallurgy, The University, Edgbaston, Birmingham, 15. No fees are chargeable for the attendance but registration is required.

British American Research Ltd.

AT a recent meeting of the Directors of British American Research Ltd., manufacturers of high vacuum equipment, resignations were accepted from The Earl of Selkirk, Chairman, and Richard S. Morse, Director.

The agreement, under the terms of which British American Research Ltd. acquired certain rights, patents, technique, and know-how from National Research Corporation, Cambridge, Massachusetts, U.S.A., has been terminated, and National Research Corporation has recently disposed of its entire holdings in this company. It has been further agreed that neither British American Research Ltd. nor its associate, Daniel Varney Ltd., will have, nor refer to, any relationship with National Research Corporation and that the use of the name, British American Research Ltd. will be discontinued.

Personal News

MR. H. H. MARDON, Head of the Plant Engineering Division of the British Iron and Steel Research Association is relinquishing his position to take up the appointment of Chief Project Engineer with Ashmore, Benson, Pease and Co. Ltd., where his first assignment will be to lead a team of engineers making a detailed study of and preparing a scheme of planned development for a large works producing metallurgical and chemical products. DR. H. R. MILLS has been appointed Acting Head of the Division; he will remain Head of the Division's Mechanical Engineering Section.

MR. R. M. GARLAND has been appointed a Director of Veeder-Root Ltd. He has been Chief Engineer for some years and has, during the past two years, acted as Deputy to the Managing Director.

MR. R. L. PARKER has taken up his duties as London Branch Manager of British Insulated Callender's Cables Ltd., in succession to MR. F. SAMUEL who is retiring on March 8th.

DR. WILLIS JACKSON, Professor of Electrical Engineering at the Imperial College of Science and Technology of the University of London, has been appointed Director of Research and Education to Metropolitan-Vickers Electrical Co. Ltd., with effect from July 1st next. This appointment, which carries with it a seat on the Board of the Company, will release the present Director, Dr. C. Dannett, for an extension of his present duties as Assistant Managing Director.

OWING to ill-health, MR. W. S. KNIGHT, Managing Director of Light Alloys Ltd., has been granted six months leave of absence by the Board, and MR. K. C. T. MARSHALL, Works Director, has been appointed Acting Managing Director. THE RT. HON. LORD ROCKLEY has resigned from the Board owing to pressure of his other commitments.

MR. HUGH O. BOURNE has retired from the position of Managing Director of Maiden and Co. Ltd., Hyde, after 42 years service with the Company. Mr. Bourne remains a Director and will continue in an advisory capacity. MR. G. B. TINKER has been appointed to the position of General Manager.

METROPOLITAN-VICKERS ELECTRICAL CO. LTD. announce a number of new appointments with effect from 1st January, 1953. In the sales organisation, MR. J. P. A. MELDRUM has been appointed Manager, Home Sales, MR. A. E. GRIMSDALE is now Special Assistant, Sales Management, and MR. J. C. WAY has succeeded Mr. Grimsdale as Sales Manager, Traction Department. MR. C. H. DE NORDWALL has been appointed Manager for South America in the Metropolitan-Vickers Electrical Export Co. Ltd., his position as Sales Manager of the Industrial Control Department of the parent company being taken by MR. G. D. HARRADINE. On the engineering side, MR. H. W. HARDERN is now Assistant Chief Engineer, Transformer Department; MR. E. L. N. TOWLE is Assistant Chief Engineer (Industrial), Electrical General Engineering Department; and MR. F. B. HOLT, Consultant (Industrial), Electrical General Engineering Department.

MR. R. B. SIMS, Head of the Rolling Laboratory of the British Iron and Steel Research Association since 1948, has relinquished that appointment in order to take up the new post of Research Manager of Davy and United Engineering Co. Ltd., Sheffield. Mr. Sims' association with B.I.S.R.A. will, however, not be entirely severed, as he will also act for an agreed period as Consultant to the Rolling Laboratory.

MR. O. W. HUMPHREYS, Director of the Research Laboratories of The General Electric Co. Ltd., left last month for a business tour of Australia, during which he will lecture to a number of technical and scientific organisations.

Obituary

WE regret to record the death on Sunday, January 11th, of Mr. Andrew Pinkerton, Chief Metallurgist of Earle, Bourne and Co. Ltd. Educated at the Royal Technical College, Glasgow, he spent three or four years with the City Analyst before joining the Rio Tinto Copper Mines in Spain, where he remained until the outbreak of World War I, returning to join the forces. His military service was distinguished and he was awarded the Military Cross early in 1918. On demobilisation, he joined the metallurgical staff of Earle, Bourne and Co. Ltd., becoming Chief Metallurgist in a year or so on the resignation of the then chief. His service with the Company was very notable, and he was responsible, in large measure, for a great deal of the technical advances made by the Company in its varied range of products.

RECENT DEVELOPMENTS
MATERIALS : PROCESSES : EQUIPMENT

Centrifugal Pumps for Use with Corrosive Liquids

AMONG the many advantages of the centrifugal pump are small size and weight, easy drive by electric motor on the same base plate, minimum wear and tear, and noiseless running. Modern methods of development have enabled pumps to be constructed of corrosion-resisting materials dealing with acids and similar corrosive liquids employed in electroplating and other electrolytic processes, as well as in the pickling and general cleaning of metals.

The construction of such pumps, however, is the work of specialists, and typical of the latest practice are the "CH" and "CHV" pumps of the Pulsometer Engineering Co., Ltd., of Reading. All parts of the pumps in contact with the liquid are constructed of suitable metals for the purpose, such as stainless steel, acid-resisting bronze, austenitic cast iron and steel, or aluminium alloys. As these metals are expensive, their weight is reduced to a minimum consistent with strength and rigidity, which are increased by a cast iron hood and a large diameter shaft well supported in external ball and roller bearings specially protected from any contact with injurious chemicals. This is important, because of the tendency of most chemically-resistant metals to be prone to seizure, and because many injurious chemicals have little or no lubricating properties.

In the "CH" pump there is a single inlet impeller of the shrouded type, surrounded by a volute casing, but in the "CHV" pump, which will handle products containing fine solids in suspension, or fibrous matter, an open type of impeller is embodied with renewable side plates rigidly fixed to the casing. These plates are adjusted as required to give proper axial alignment to take up any wear if the liquid is abrasive, maintaining the correct clearance and ensuring also that there is little or no pressure on the gland. The casing has an axial suction facing, studded to take British standard pipe connections, whilst the delivery branch is tangential, flanged and drilled and provided also with a connection for a gauge.

Careful design of the impeller reduces the pressure on the stuffing box to a minimum, so that little or no leakage takes place, whilst in addition a deep stuffing box is fitted having a double gland and double lantern bush. The first traps and leads any leakage to the drain dish, and can be connected to a water service for condensing or diluting harmful liquids, or for the circulation of a sealing liquid, whilst the second lantern bush can be used for a grease or similar seal and for lubrication of the packing in the outer gland.

In the ordinary standard construction, the shaft is made of a similar material to the pump parts, while protection is also given to the bearing, against the entry of liquid from the gland, by a combined water thrower and labyrinth seal which is fed with grease from the bearings, each of which are provided with grease nipples.

Pulsometer Engineering Co., Ltd., Reading.

Recording Balances

NEW recording balances of robust industrial design have recently been developed by Messrs. Testut, Paris. These instruments draw a weight-time curve on a drum 150 mm. high × 240 mm. circumference: strip recording charts are available for panel mounting. The sensitivity may be as high as 1 mg./mm., and the time axis is determined according to the particular application, e.g., one revolution of the drum in 1, 2, 4, 6, 12, 24 hours, etc.

These balances have a variety of uses and recent applications include the determination of evaporation rates of mixed solvents at different temperatures, as in the drying of paints; the study of gas-solid reactions, as in the carburisation of steels in hydrogen-methane mixtures; the study of the roasting and calcination of ores; the study of the firing of bricks and refractories; and the checking of combustion efficiency as measured by flue-gas density.

The principle of operation is new: the beam is continuously oscillating but is maintained in a state of dynamic equilibrium through a special platinum-gold contact fixed to it energising a relay which controls a servo-motor. Equilibrium of the balance is restored on the Chainomatic principle by operation of the motor. The balances can safely be used in a works in conditions of vibration and, since they are completely enclosed in a metal case, they are also dust proof.

The balances may be adapted for use with high temperature furnaces in controlled atmospheres, for recording weight changes of specimens, and for studying chemical reactions: they can also be supplied for use with low temperature ovens. A weight-time curve is normally recorded, but means can be provided for recording weight-temperature curves for special applications. The recording unit can be applied to existing types of weighing equipment (by suitable adaptation) to record continuous changes in weight of total loads up to hundreds of kilograms.

The importation of these instruments is subject to the granting of a Board of Trade licence.

Agents: *Griffin & Tatlock, Ltd., Kemble Street, Kingsway, London, W.C.2.*

New Electrode for Manganese Steel

THE Quasi-Arc Co., Ltd., have entirely redesigned their well known Manganoid electrode, which has been in use for many years for the welding of 12/14% austenitic manganese steel. Manganoid (New Type) electrodes are fully extruded, and are particularly easy to use with both direct and alternating current supplies. Recommended for the reinforcement of manganese steel excavator buckets, digger teeth, rock crusher jaws and manganese steel railway points and crossings, they deposit crack-resisting weld metal which work hardens rapidly to provide maximum resistance to wear, impact and abrasion.

The Quasi-Arc Co., Ltd., Bilston, Staffs.

CURRENT LITERATURE

Book Notices

THE THEORY AND PRACTICE OF THE STRENGTH TESTING OF MATERIALS

Volume Six of Selected Government Research Reports. Published by Her Majesty's Stationery Office for the Department of Scientific and Industrial Research. In two parts. Price for each part 55s. (11 dollars U.S.A.); by post 6d. extra.

Like its predecessors, Volume Six of Selected Government Research Reports consists of reports on research work carried out for the Ministries of Aircraft Production and Supply.

The thirteen reports included in Part I are concerned with the theory of strength and deformation of materials. Among the theories described are those concerned with indentation and hardness, plastic and elastic deformation, and the behaviour of tubes under internal pressure. There are also reports on the behaviour of materials in compression, the phenomenon of notch brittleness, and the theory of extrusion of metals. The publication includes an outline of general methods of solution of the axially symmetric problem in elasticity, and a theory on the yielding and plastic flow of anisotropic metals.

Part II, dealing with testing methods and test results, contains seventeen reports. The use of mechanical and electronic methods of measuring stress is outlined, and a nomographic means of solving the equations involved in the X-ray method of measurement is described. A number of reports deal with stress and strain measurements in tubes, sheets and bars and in cylinders and spheres. There are also sections dealing with the strength requirements in butt and spot welds in various metals.

PAINTING PRACTICE FOR ALUMINIUM

Information Bulletin No. 20 of the Aluminium Development Association, 33, Grosvenor Street, London, W.1. Price 2s.

Since the publication of A.D.A. Information Bulletin No. 13, "Surface Finishing of Aluminium and its Alloys," significant advances have been made, and the position has been reached when the information available in the form of firm requirements justifies a separate Bulletin (No. 20) on painting practice. This publication opens with a broad survey which makes clear that the painting of aluminium largely follows good established practice for other metals, with certain modifications to suit the particular material. Subsequent sections deal with cleaning and degreasing, pre-treatment where necessary, the choice of paint system—divided between single-coat systems and multi-coat systems—and the repainting of small and large components and structures.

Trade Publications

At the Fourth International Mechanical Engineering Congress, held in Sweden last June, Dr. A. B. Everest presented a paper on the engineering properties and applications of spheroidal graphite cast iron. After dealing with the physical and mechanical properties, Dr. Everest proceeded to discuss production characteristics, modifications of S.G. iron, hot and cold working, and service properties, concluding with a review of applications based on properties. This paper has now been reprinted and is issued by The Mond Nickel Co. Ltd., Sunderland House, Curzon St., London, W.1.

We have received from Accles & Pollock, Ltd., Oldbury, Birmingham, their latest publication dealing with practice and specifications. This booklet has been issued with the object of providing data for designers and users of tubes and tubular parts. Following an introductory section giving general information on such things as finish, heat treatment, available lengths, specifications and tolerances, further sections are included giving details of size, composition, treatment and mechanical properties of the range of Accles and Pollock tubes and tubular products, in carbon steel, alloy steel and non-ferrous materials.

A recent addition to the Tornado range of fan engineering equipment is the bifurcated fan unit which is dealt with in Publication 28, which can be obtained from Keith Blackman, Ltd., Mill Mead Road, Tottenham, London, N.17. The special feature of this fan, which has been designed to meet the needs of many applications for the mechanical exhausting of dust or fume-laden air or gases, is that the fan casing is split across a diameter and opened out to provide a separate chamber for housing the driving motor, thus completely isolating it from the fumes. Obnoxious, corrosive or inflammable gases may be dealt with at reasonably high temperatures.

The various items in the complete new range of cutting coolants and lubricants offered by Regent Oil Co., Ltd., are fully described in the Company's latest publication "Lubricants and Coolants for Cutting and Grinding." Broadly classified into eight type-groups, it is interesting to note the inclusion of transparent sulphurised oils, as well as transparent non-corrosive oils. An "extreme pressure" product, which has proved very successful in the machining of the Nimonic alloys is also featured.

Books Received

"An Outline of Metallurgical Practice" (3rd Edition), by Carle R. Hayward. This edition is sponsored by American Smelting and Refining Company. 728 pp. inc. 445 illustrations and index. New York, Toronto and London, 1952. D. Van Nostrand Company, Inc., and Macmillan & Co., Ltd. $10.00 or 75s. net.

"Chemische Technologie—Metallurgie-Allgemeines." Edited by Dr. Ing. Karl Winnacker and Dr. Ing. Ernst Weingaertner. Volume 5. 846 pp. inc. indices, illustrations and tables. München, 1953. Carl Hanser Verlag. 71.50 DM. Cloth Bound 74.50 DM.

"Visual Lines for Spectroscopic Analysis." By D. M. Smith, 2nd Edition. 102 pp. London, 1952. Hilger & Watts, Ltd. 16s. net.

"Atomic Theory for Students of Metallurgy." 2nd (revised) edition. William Hume-Rothery. Institute of Metals Monograph and Report Series No. 3. 331 pp. inc. indices and numerous illustrations. London, 1952. The Institute of Metals. 21s.

"Investment Castings for Engineers." By Rawson L. Wood and Davidlee Von Ludwig. 477 pp. inc. bibliography and index. New York, 1952. Reinhold Publishing Corporation. Chapman & Hall, Ltd. 80s. net.

Cambridge

APPARATUS FOR METALLURGICAL ANALYSIS

MODERN OUTFITS of special interest to the metallurgical chemist, both for research work and for routine analyses. They are described in separate publications which contain much valuable information.

POLAROGRAPH

For the rapid electro-chemical analysis of solutions, enabling traces of metals and other substances to be determined by the Heyrovsky dropping mercury electrode method. Described in

SHEET 302-V

TITRATION APPARATUS

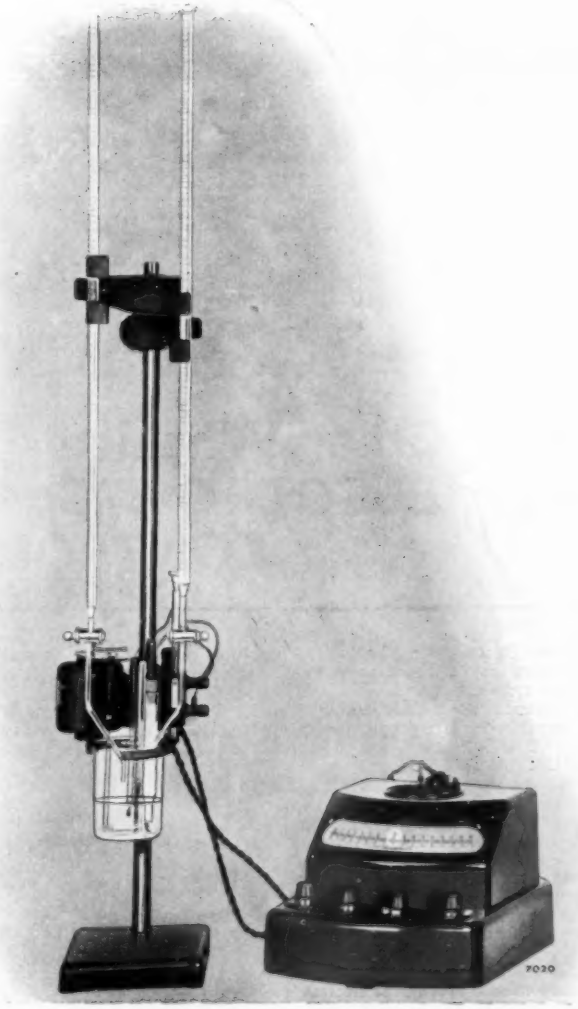
For the analysis of steels containing chromium and vanadium, and any other applications where a titration method is desirable. Especially useful for determining end-points in coloured solutions. Described in

SHEET 247-V

pH METERS

Valuable in making titrations of oxidising or reducing agents, and for routine analyses af various alloys and steels. Described in

FOLDER 72-V



Potentiometer Titration Outfit

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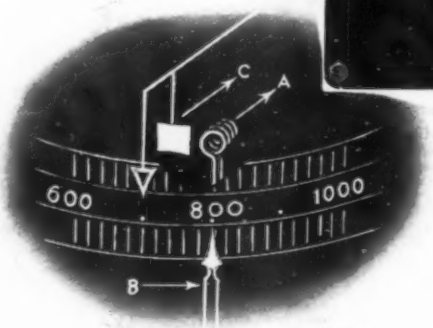

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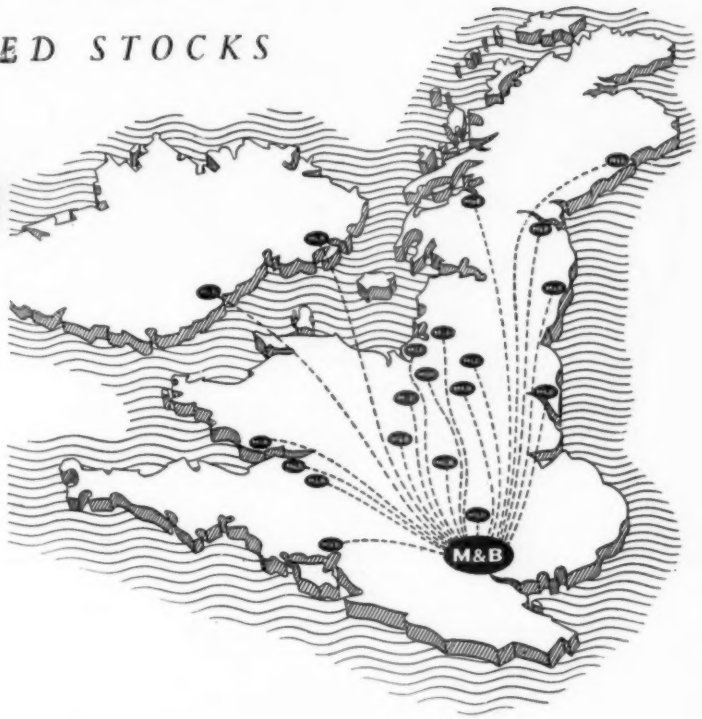

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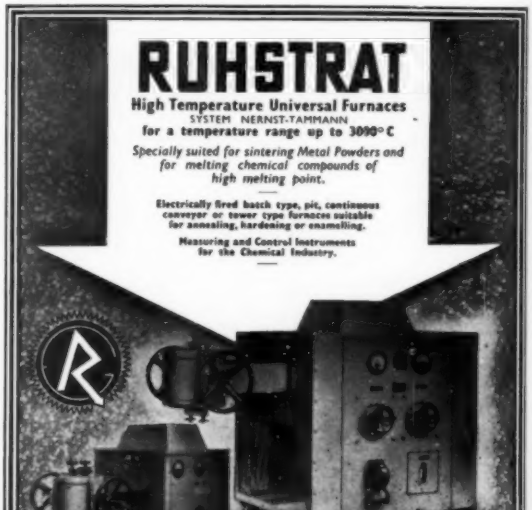

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LABORATORY METHODS
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INSTRUMENTS AND MATERIALS

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Recent Developments in Metallurgical Analysis III—Gravimetric Analysis

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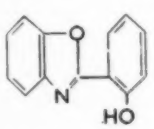
Many advances have been made in analytical methods during the past few years. The present series of articles reviews some of these developments under the general headings: I—Electrochemical Analysis; II—Titrimetric Analysis; and III—Gravimetric Analysis. Such is the volume of papers forthcoming in these three main divisions, however, that it is only possible to touch on the more interesting developments which have appeared within the past few years, although references have been made to work previous to this period where it has been felt necessary to trace the logical development of some of the methods.

SEVERAL new precipitants and a few modifications to existing gravimetric methods have been described in the past few years. In the concluding article of this review, some of these developments are discussed.

NEW PRECIPITANTS

2-(o-Hydroxyphenyl)-Benzoxazole for Cadmium

The most popular organic reagents used in the gravimetric determination of cadmium are undoubtedly oxine, quinaldic acid and anthranilic acid. While it is true that these reagents have been used successfully for the determination of cadmium in many metallurgical materials for many years, it is also true to say that in all three cases no other heavy metals should be present in the analysis solution. In June, 1952, a new reagent for the gravimetric determination of cadmium was described, which could be used for cadmium in the presence of other heavy metals with very little interference[1]. Very appropriately, the reagent was developed in Pittsburgh, and it has already achieved considerable popularity in this country.



2-(o-Hydroxyphenyl)-Benzoxazole

2-(*o*-hydroxyphenyl)-benzoxazole was found to be more selective for cadmium than any other organic precipitant known. The only interfering metals were copper, nickel and cobalt, and these were readily dealt with by simple measures. The cadmium precipitate was completely soluble in acid solution, while the copper salt of the reagent was insoluble. Walter and Freiser found that precipitation of copper was complete from *p*H 3·5–4, while cadmium did not begin to precipitate till *p*H 6·5 in the presence of large amounts of tartrate. Since precipitation of cadmium was complete between *p*H 11 and 12, they found it possible to obtain a clear-cut separation and determination of cadmium in the presence of appreciable amounts of copper. Cobalt and nickel in moderate amounts had to be removed by precipitation with dimethylglyoxime and α-nitroso-β-naphthol.

While the reagent is probably not available commercially, it was very simply prepared[2] by heating a mixture of *o*-aminophenol and salicylamide in molar proportions for 4 hours, till no more ammonia was evolved. The product was then distilled and purified by recrystallisation from alcohol several times. The pure product melted at 124° C., and was obtained in 48% yield. A 1% w/v solution of the solid in 95% ethanol was used as the reagent. The yellow precipitate, dried at 130°–140° C., gave on analysis a formula corresponding to $Cd(C_{13}H_8O_2N)_2$. The factor for cadmium was 0·2109. The procedure described by Walter and Freiser necessitates that precipitation be carried out at 60° C., adding the reagent first, and bringing the *p*H up to 11 by addition of 1 N sodium hydroxide. The solution was maintained at 60° C. for fifteen minutes, and then allowed to cool to room temperature: the authors do not specify any particular standing time. The precipitate was washed several times with ammoniacal 50% ethanol and dried for at least two hours, at 130°–150° C. A table is given showing results obtained on solutions of cadmium containing two-fold excess of ions such as Ba, Mg, Fe^{III} Hg, Zn, Al, Pb, As, Bi, Mn, Cr, etc., and the effect of equal amounts of Co and Ni were shown to give results which were high by about 5–10%. This new precipitant for cadmium appears to be efficient and highly selective, and can therefore be confidently recommended.

Triphenylmethylarsonium Iodide for Cadmium

Another precipitant recently proposed for the gravimetric determination of cadmium, overcomes the difficulty usually associated with the determination of this metal in the presence of zinc[2]. Unfortunately, the

reagent has a much more restricted field of application than the previous one, because an appreciable number of other ions interfere with the determination. The reagent, triphenylmethylarsonium iodide, precipitates cadmium as $[(C_6H_5)_3\ CH_3As]\ CdI_2$, giving an excellent conversion factor, since the precipitate only contains 8·903% cadmium, and can be weighed as such after drying at 105°–110° C.

A 0·5% aqueous solution of the reagent was added to the solution containing cadmium, so that a three-fold excess was present. The precipitation was best carried out in hot solution, the solution being allowed to cool to room temperature for one hour after adding the reagent, and then cooled under running water for another half-hour. The precipitate was filtered through sintered glass and washed with 0·5% potassium iodide before drying. When excessively large amounts of zinc were present, it was found advisable to add a 10% solution of potassium iodide before adding the precipitant, since the tendency for zinc to form the complex tetraiodide ion reduced the iodide ion concentration to such an extent that incomplete precipitation of cadmium occurred. Satisfactory results for amounts of cadmium from 1 to 100 mg. were quoted. The interfering ions were: Sb, As, Bi, Cu, Pb, Hg and Ag. The interference from these ions, which also form insoluble compounds, may be overcome, to a considerable extent, by boiling the acid solution with iron wire and filtering before adding the reagent.

Quinoline–8–Carboxylic Acid for Cadmium, Copper and Iron

Quinoline–8–carboxylic acid was first proposed as a reagent for copper in 1941, by Majumdar[3]. The reagent was prepared from 8 methyl quinoline by oxidation of the methyl group. Excellent results were obtained with amounts of copper varying from 6 to 250 mg. A 1% alkaline solution of the compound was used to precipitate the copper as $Cu(C_{10}H_6O_2N)_2$, in which form it was weighed, giving a good conversion factor. The *p*H of the solution for analysis was loosely adjusted by making alkaline with ammonia, and then slightly acid by addition of a few drops of 0·1 N mineral acid. Gilbraeth and Haendler[5] have re-examined the method, and commented favourably on the reagent. They also found that close control of *p*H allowed the reagent to be used for the separation of copper from many other metals. The determination of copper in the presence of cobalt and zinc has subsequently been described by the original author[4].

Simultaneously[4], methods for the gravimetric determination of cadmium and iron, using the same reagent were described. The cadmium precipitate had the formula $Cd(C_{10}H_6O_2N)_2$, and was dried after washing at 110° C., as opposed to 150° C. in the case of the copper precipitate. In the procedure proposed for the precipitation of cadmium, an excess of a solution of the sodium salt of quinoline–8–carboxylic acid was added to an acid solution containing cadmium ions. The *p*H was then adjusted by making the solution alkaline to bromothymol blue, and the precipitate filtered through sintered glass, washed with water and dried before weighing. The precipitation was carried out at room temperatures. The interference of copper, arsenic, antimony and bismuth was prevented by addition of sodium potassium tartrate.

In the gravimetric determination of iron[11], the reagent was added to a hot solution containing sodium potassium tartrate. The dark red solution thus produced did not yield the precipitate very readily, and was, therefore, allowed to cool overnight. The violet-red crystals were then filtered, well washed with cold water, and dried. The precipitate would appear to be less stable than those of the cadmium and copper determinations, as it was air dried and weighed as a mono-hydrate $Fe(C_{10}H_6O_2N)_2.H_2O$. The method is more lengthy than those described for cadmium and copper, and although the conversion factor is good, the necessity for air drying is an undesirable feature in metallurgical analysis.

Whilst discussing the subject of the determination of iron by means of quinoline carboxylic acid, it is interesting to note a recent paper by Hungarian workers[6], which purports to achieve an easily filterable form of ferric hydroxide. The solution was made slightly ammoniacal, and the excess ammonia boiled out. A saturated solution of hydrazine was then added and the solution heated with stirring till the precipitate, in which the iron was present partly in the ferrous and partly in the ferric state, was brown-black or dark-brown in colour. The precipitate was easily filtered, washed and ignited to ferric oxide.

Phenylarsonic Acid and Gallic Acid for Lead

Indian workers[7] have examined the use of phenylarsonic acid for the determination of lead. An excess of the reagent (two-and-a-half- to three-fold is sufficient) was added to the solution containing lead and the *p*H adjusted to 6·8–7·4 by careful addition of ammonia. The precipitate thus obtained, contained 50·18% lead as opposed to the 50·86% lead required by theory. Sodium, potassium and calcium, but not ammonium or the other alkaline earths, interfered by co-precipitation. By and large, the method does not appear to be an attractive one. The fact that some of the alkali and alkaline earth metals interfere, while other metallic elements usually associated with lead in alloys are not mentioned, is ominous.

Gallic acid was used by Mayr[8] for the gravimetric determination of lead. To the solution containing lead as its nitrate, a two- to five-fold excess of a 1% aqueous solution of gallic acid was added, and the solution was buffered with sodium acetate. The precipitate was coagulated by maintaining the solution at 75°–100° C. for some time, and was then filtered through sintered glass and washed with water at 40° C. It was dried at 110°–120° C. for 1½ hours and weighed as $Pb_4(C_6H_2O_3\cdot COO)_2\cdot \frac{1}{2}H_2O$. The method is said to be suitable for the determination of lead in the presence of bismuth.

The Willard and Smith reagent, a 20% solution of hydrochloric acid in butyl alcohol has been used to precipitate the chlorides of many metals since it was first proposed for the separation of sodium and lithium. Lead chloride has now been shown to be insoluble in *n*–butanol containing small amounts of hydrochloric acid. Bismuth chloride and the chlorides of other elements usually associated with lead in alloys were very soluble in the same medium. In the method proposed by Kallmann[9], the chlorides of the metals were treated with a 2% solution of hydrochloric acid in *n*–butanol and the lead chloride was recovered by filtration through sintered glass, dried and weighed. Bismuth was determined in the filtrate as the oxychloride.

Metals and alloys were opened out by solution in hydrochloric acid, hydrogen peroxide or dilute nitric acid. Tin, antimony and arsenic were almost completely removed as their volatile chlorides by repeated evaporation with hydrochloric acid. Bi, Cu, Zn, Cd, Fe, Al, Cr, Mn, Mg, Co, Ni and the residual amounts of Sn, Sb and As did not interfere with the lead determination. Na, K, Ba, Sr and Ag also form chlorides which are insoluble under these conditions, but these are not normally present in most lead alloys.

1 Amino-4, *p*–Aminophenylnaphthalene and 4, 4′-Diaminostilbene for Tungsten

A recent investigation of the application of substituted benzidines and related compounds as reagents in analytical chemistry has revealed that at least one of these compounds, 1 amino–4, *p*–aminophenylnaphthalene has valuable tungsten precipitating properties, and may be used for the gravimetric determination of this metal in the presence of molybdenum[10]. Benzidine itself has been used as a tungsten precipitant for many years, but it has not achieved much success as a reagent for tungsten, possibly because of its lack of selectivity and the ease with which molybdenum co-precipitates. Whereas precipitation of both metals in neutral solution is complete, only 90% recovery is obtained with tungsten in 0·5 N acid and molybdenum is scarcely precipitated.

With 4, 4′-diaminostilbene, the authors found that both tungsten and molybdenum were precipitated quantitatively in neutral solution, while at a final acidity of 0·7 N with respect to free hydrochloric acid, tungsten was precipitated almost completely and molybdenum not at all. Furthermore, there was no co-precipitation of molybdenum at this acidity. When the acidity was reduced to 0·5 N, slightly low results were still obtained for tungsten and appreciable co-precipitation from molybdenum was observed. The reagent was not recommended because occasional inexplicable results were obtained.

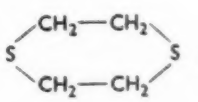
Both tungsten and molybdenum were precipitated quantitatively by 1–amino–4, *p*–aminophenylnaphthalene from neutral solution. In 0·7 N hydrochloric acid, tungsten was precipitated almost quantitatively by the reagent, whereas molybdenum remained in solution. No co-precipitation of molybdenum occurred at an acidity of 0·7 N hydrochloric acid, but it was marked in 0·5 N acid. In 1 N acid, low results were obtained unless the solution was stored overnight. Cu, Cd, Al, Cr, Ni, Zn, Mg and the alkali metals did not interfere, but ferric iron and oxidising agents had to be absent. A 1% solution of the hydrochloride in water was used as the reagent, and a precipitation time of ½–1 hour was observed. The precipitate was filtered on a pulp pad, ignited at 750° C. in a platinum crucible, and weighed as tungstic oxide.

In passing, the abstracts reveal that Chinese workers have been continuing the war-time search for substitutes for cinchonine for the determination of tungsten. Amongst reagents recommended by these workers, are a 0·2% aqueous solution of *p*–aminoazobenzene hydrochloride, a 0·33% solution of Chrysoidine R and a 0·1% solution of Bismark Brown. The last two were found to be satisfactory when added to solutions distinctly acid with hydrochloric acid[11]. Others[12] claim to have achieved satisfactory results for tungsten by slow hydrolysis of the chlorotungstate complex in hydrochloric acid, or of the oxalatotungstate complex by evaporation with strong sulphuric acid. The tungstic acid thus obtained was yellow, compact and easily filtered. An error less than 0·15% was quoted.

Dithiane and Phenylboric Acid for Mercury

A new method for the gravimetric determination of divalent mercury dependent on precipitation of this ion as white, sparingly soluble $Hg.(C_6H_5)_2$ has been outlined by Holzbecher[13]. The precipitation was effected by addition of phenylboric acid to a solution buffered with sodium acetate in the presence of nitrate, sulphate, tartrate or citrate ions, or in ammoniacal solution if chloride, bromide or thiocyanate were present. In the recommended procedure, 5–25 ml. of a 1% solution of phenylboric acid were added to 10–75 ml. of solution containing 0·005–0·15 g. of divalent mercury, followed by 5–20 ml. of 10% sodium acetate. The precipitate was filtered through a porcelain filter crucible and washed with a cold saturated solution of the salt, and finally with two 5 ml. portions of water. The precipitate was dried at 70° C. and weighed *in vacuo*. In the presence of halide ions the sodium acetate buffer was replaced with concentrated ammonia. Unfortunately, no mention is made of the interference to be expected from other ions, nor of the sensitivity of the method.

The same author also proposed a useful test for mercuric mercury based on the formation of a blue-violet precipitate with the phenylhydrazone of pyruvic acid. The precipitate was soluble in organic solvents, giving a red-brown solution. The presence of tetravalent cations inhibited the reaction, while cadmium and zinc salts enhanced it.



p-Dithiane
(Diethylenedisulphide)

p–Dithiane (diethylenedisulphide) has been shown by Schroyer and Jackman[14] to be a satisfactory reagent for the detection and determination of mercury. Mercury in the divalent state in hydrochloric acid solution was treated with a slight excess of a 2% solution of the reagent in 95% alcohol. The precipitate obtained had the constitution of an addition product of mercuric chloride, with the reagent, viz., $HgCl_2.C_4H_8S_2$. In the procedure recommended by the authors, the solution containing 50–100 mg. of mercury in 100 ml. of 0·2 N hydrochloric acid, and containing a 30% excess of the reagent, was allowed to stand for 24 hours before filtration through sintered glass. The precipitate was well washed with water and dried for 2 hours at 100° C. The procedure was successfully applied to several mercury alloys. Copper, lead and silver interfered with the determination.

An earlier method for mercury proposed by Indian workers[15], employs copper biguanidine chloride as the precipitant. The precipitate obtained by this method corresponded to the formula $[Cu(C_2N_5H_7)_2]HgI_4$, providing a more favourable conversion factor than that obtained with dithiane. The method appears to be suitable for the analysis of amounts of mercury less than 100 mg. in 100–200 ml. of solution. Before addition of the reagent, the solution was made 1% with respect to potassium iodide and the time of standing was not less than four hours. In the original method, the precipitate was dried to constant weight at 105° C.

Diphenylhydantoin and Diphenylthiohydantoin for Copper, Nickel and Cobalt

The sodium salt of diphenylhydantoin gives a green precipitate with nickel salts in acid solution and a blue-violet precipitate in ammoniacal solution. The precipitate given in acid solution was found by Tamayo and Marques[16] to coagulate readily on boiling, and they attributed the composition $(C_{15}H_{11}O_2N_2)$ $Ni.4H_2O.2NH_3$ to the blue compound obtained from strongly ammoniacal solution. The method would appear to furnish as accurate a gravimetric method for nickel as that obtained with the classical dimethylglyoxime reagent proposed by Tschugaeff in the opening years of the century.

Garrido[17] has recommended diphenylthiohydantoin as a reagent for cobalt. The sodium salt of the reagent gives a light blue precipitate with cobalt salts in neutral solution, and a bright violet precipitate in ammoniacal solution. In the recommended procedure, use was made of the latter — $(C_{15}H_{11}N_2OS)_2Co.2NH_3$ — which could readily be filtered and dried. A neutral solution containing 0·02 g. of cobalt in 20 ml. was treated with 10 ml. of concentrated ammonia and 10 ml. of 2% sulphuric acid. The solution was diluted to 100 ml., heated to boiling and treated with 10 ml. of a 2·7% solution of the reagent.

Both authors, Tamayo and Garrido[18] unite to indicate the use of the sodium salt of diphenylhydantoin for the gravimetric determination of cupric copper. In ammoniacal solution a compound having the composition $C_{30}H_{22}N_4O_4.Cu.2NH_3$ was obtained which lost ammonia on heating for 30 min. at 180°–200° C. to give an inner complex compound $(C_{15}N_{11}H_2O_2)_2Cu$. The authors claimed an accuracy of ± 0·5% for the method. Further work requires to be done on all three methods before a true assessment of their value can be given.

Picrolonic Acid and α–Picoline for Manganese and Beryllium

Gusev[19] has used picrolonic acid as precipitant for manganese in a method proposed for the gravimetric determination of this ion. In the method described, 15 ml. of a 0·01 N solution of the reagent were added to 10 ml. of the manganese solution containing 0·005 g. of the ion. The solution was warmed to 50° C. and allowed to stand for 2 hours at room temperature. The precipitate was washed with water and dried at 105° C. Ions such as iron, chromium, aluminium and titanium did not interfere.

The proposal of α–picoline as a reagent for beryllium is also due to Russian workers[20]. The method enables beryllium to be separated from zinc, manganese, nickel, cobalt, magnesium and the alkaline earth metals. Beryllium hydroxide was precipitated by adding the reagent to a boiling solution of the beryllium salt containing ammonium chloride, till a methyl orange indicator present in the solution turned yellow. The precipitate was coagulated by maintaining the solution at the temperature of a boiling water bath for some time, washed with a dilute solution of ammonium nitrate containing the reagent, dried and ignited to BeO at 1,000° C. A re-precipitation of the hydroxide was necessary in the presence of excessively large amounts of zinc, manganese, cobalt and nickel.

Carboxylic Acid Reagents for Thorium

The past few years have revealed a resurgence of interest in the analytical chemistry of thorium, particularly amongst Indian research workers. This interest is no doubt caused by the intensive development of India's mineral deposits, particularly the monazite sands.

Most methods for the separation of thorium from the cerium earths require a double precipitation, but in the opening decade of the present century Kolb and Ahrle[21] proposed a new method using benzoic acid as precipitant, which resulted in a sharp separation of thorium from a large excess of rare earths. Benzoic acid was not favoured by Neish[22, 23] who preferred the *m*–nitro derivative as precipitant. Indian workers have re-examined the benzoic reagent[24] and in a later paper have modified the original procedure by increasing the reagent concentration from 1 to 2% in hot solution, thus obtaining a sharper separation of thorium from the rare earths. In the procedure recommended by Rao[25] and his co-workers, 10 g. of ammonium chloride were added to 100 ml. of solution containing 0·1 g. ThO_2 and neutralised to Congo Red. The solution was boiled, treated with 100 ml. of boiling 2% benzoic acid and maintained at its boiling point for a further 10 minutes. The precipitate was then allowed to settle, filtered and washed with hot 0·25% benzoic acid before ignition to ThO_2. A double precipitation after solution of the first precipitate in hot 6 N hydrochloric acid gave a complete separation from uranium, even when the latter was present in a hundred-fold excess.

Camphoric acid also precipitates thorium. The precipitation was found to be complete in a solution buffered with sodium acetate at *p*H 4·6 or higher[26]. Cerite earths were precipitated above *p*H 6·2, but by dissolving the first precipitate deposited at *p*H 4·4, in 3 N nitric acid and re-precipitating at *p*H 4·4, a good separation was obtained. The precipitate was washed with hot 1% camphoric acid, dried to constant weight at 105° C., and weighed as ThO_2 after ignition.

Cinnamic acid[27] precipitates thorium from solutions of *p*H 1·9 or more, and by a double precipitation at this *p*H, after dissolving the first precipitate in 7·5 N nitric acid, thorium can be separated from 350 times as much uranium. The precipitate was of inconstant composition and had to be ignited to thoria. The white precipitate was very flocculent, but settled well after boiling. At *p*H 2–2·6, thorium may be separated from as much as a fifty-fold excess of cerite earth in one operation[28].

Anisic acid[29] (*p*–methoxybenzoic acid), which was also proposed as a reagent for thorium and its separation from the rare earth metals, must be considered inferior to cinnamic acid. A single precipitation in neutral solution separated thorium from uranium when the latter was present in roughly equivalent amounts. A double precipitation was required when amounts larger than a two-fold excess were present. Most divalent elements did not interfere with the determination of thorium[30], but considerable co-precipitation occurred with chromium. Zirconium, vanadium and titanium interfered.

Succinic acid was found by Rao and co-workers[31] to form a fairly insoluble precipitate with thorium, but under the *p*H conditions required, the rare earths were also thrown down. On the other hand, adipic acid gave quantitative precipitation, and by a double precipitation at *p*H 4·2–4·4 it was found possible to get a clear-cut

separation of thorium from the cerite earths. Homogeneous precipitation using ammonium picrate as reagent[32] was found to precipitate thorium completely at *p*H 4·8–5·2 by heating for 15 minutes on a water bath. The ammonium salt of 2, 4–dinitrophenol was also effective[32] at *p*H 4·8–5·2. Ammonium furoate[33] appears to be superior to the two previous reagents, however. At *p*H 2 it was effective in precipitating as little as 2·2 mg. of thorium in the presence of fifty-fold amounts of cerite earth. Sodium sulphanilate[33] appeared to be still more effective for it was used to determine as little as 1 mg. of thorium in the presence of 100 mg. amounts of cerite earths. In all instances the precipitates were ignited strongly before weighing.

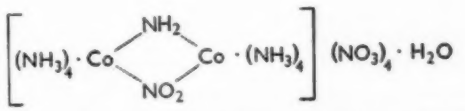
o–Toluic acid[34] has also been used to precipitate thorium from neutral solution. The flocculent white precipitate which was obtained from boiling solution and washed with 0·05% reagent solution before ignition, was contaminated in the presence of cerite earths, but at *p*H 3–4, accurate results for thorium were recorded even in the presence of considerable amounts of these elements. In the same paper, the thorium precipitating properties of acetylsalicylic acid were examined[34]. No precipitation was observed when a cold saturated solution of the reagent was added to a solution of thorium ions at room temperature and *p*H 2·6–3·8, but when the solution was boiled and treated with sodium acetate, precipitation became complete. When cerite earths were present in more than a five-fold excess they were carried down, but re-precipitation after solution of the first deposit in 7·5 N nitric acid gave a product which yielded pure thoria on ignition. Excellent results were obtained with both acetylsalicylic and *o*–toluic acids. *o*–Chlorobenzoic acid is a useful precipitant for thorium in the presence of 50–60 times as much uranium. Murthy and Rao[35] carried out the precipitation at a *p*H of 2·6–2·8. The method appears less satisfactory than the cinnamic acid method previously described.

Neish's original *m*–nitrobenzoic acid method has recently been re-investigated by Osborn[36]. Using a reagent containing 4 g. of the acid in 1 litre of water, he found it an excellent precipitant for thorium, zirconium, cerium, hafnium and mercury and all quadrivalent cations except titanium.

Quinaldic acid, examined by Erametsa[37] as a reagent for thorium, precipitated the latter quantitatively in cold solution in the presence of the rare earths, but aluminium, beryllium, chromium and uranium interfered. Hydrolytic precipitation with pyridine has been used to separate thorium from many divalent metals. The solution containing ammonium chloride and ammonium nitrate was boiled and treated with 20% aqueous pyridine till added methyl orange indicator turned yellow[38]. Finally, Ryan and his co-workers[39] have employed a 0·2% solution of ferron [7–iodo–8–hydroxyquinoline–5–sulphonic acid] to separate thorium from tungsten, the rare earths, titanium, nickel and cobalt. The *p*H of precipitation was 2–3·5 and the determination was finished by ignition of the precipitate to ThO_2 at 900° C. before weighing.

Hexammino Cobaltic Tribromide and Octammino–μ–Amino–μ–Nitro Dicobaltic Nitrate for Sulphate

The classical method for the determination of sulphate by precipitation with barium chloride is subject to co-precipitation errors with many ions. The most serious limitation is undoubtedly the interference due to the nitrate ion, as nitric acid is almost always used to ensure complete oxidation of the sulphur to sulphate ion. This interference is usually overcome by fuming down with hydrochloric acid before carrying out the precipitation. An alternative method uses benzidine as reagent, but the relatively high solubility of benzidine sulphate and the large number of foreign ions which disturb the determination, render the method inferior to the barium sulphate method. Recently Mahr and Kraus[40] have shown that the sulphate ion may readily be precipitated and determined as hexammino cobaltic bromosulphate. This compound is very insoluble in aqueous acetone or alcohol. In the method described, the sulphate solution was adjusted to *p*H 2, an acidic solution of hexammino cobaltic tribromide and ammonium bromide in aqueous methanol was added, and the organic solvent content of the precipitation medium brought to 30%. The precipitate was readily filtered, dried and weighed, or could be determined titrimetrically or colorimetrically. The authors recommended the gravimetric method as being more accurate, but slightly tedious.



Octammino-μ-Amino-μ-Nitro Dicobaltic Nitrate

The work of Mahr and Krauss appears to have led Belcher and Gibbons[41] to examine a series of the co-ordination compounds of cobalt which possess difficultly soluble sulphates. As a result of their investigations, these authors proposed the compound octammino–μ–amino–μ–nitro dicobaltic nitrate as a reagent for the gravimetric determination of sulphate. The sulphate of the Belcher/Gibbons reagent was distinctly more soluble than barium sulphate, but the freedom from co-precipitation errors and even interference from the nitrate ion were favourable features. Iron and aluminium interfered by hydrolysis under the *p*H conditions employed, but addition of ethylenediamine tetra-acetic acid held these ions in solution. Phosphate interfered by precipitating an insoluble salt at *p*H values less than 5. The solubility of the sulphate was approximately ten times that of barium sulphate, being approximately 22 mg./litre at 25° C. Neither the common alkali nor alkaline earth elements interfered, nor did any of the common anions such as chloride, fluoride or nitrate. In the recommended procedure, the solution for analysis was evaporated to small bulk and a 1% solution of the reagent was used. The precipitation medium was made 25% with respect to acetone and allowed to stand for 4 hours before filtering through sintered glass. The precipitate was washed with 25% aqueous acetone and finally with acetone. The air-dried compound retained two molecules of water of crystallisation, while the oven-dried compound (110° C.) was anhydrous.

o–Dihydroxy Compounds and 5, 6–Benzoquinoline for Germanium

Bevillard[42] and his co-workers have recently investigated a series of organic compounds containing two phenolic hydroxyl groups in the ortho position with a

quinoidal structure, or mixtures of a quinone with an *o*–diphenol for the precipitation of germanium in acid solution. Gallocyanine gave a precipitate with 2×10^{-5} g. of germanium, while the sensitivities of Modern Violet, trihydroxy aurin, purpurogallin, 3, 4–dihydroxyazobenzene, and hematoxylin were 5×10^{-6}, 3×10^{-7}, 1×10^{-5}, 4×10^{-5}, and $1{\cdot}5 \times 10^{-6}$ g. of germanium[43]. The reagent selected for the gravimetric determination of the metal was a 1% solution of 3, 4–dihydroxyazobenzene in ethanol and hydrochloric acid. Precipitation was claimed to be complete[44].

The use of 5, 6–benzoquinoline was proposed by Willard and Zuehlke[45]. The reagent was prepared by the addition of 5 g. of oxalic acid in 50 ml. of water to 10 g. of 5, 6–benzoquinoline, heating and filtering the solution before dilution to 500 ml. In the recommended procedure, the germanium solution was heated with oxalic acid to convert to the trioxalato germanic acid before addition of the reagent solution. The solution was filtered after standing overnight and the precipitate washed with dilute reagent and oxalic acid before ignition in a platinum crucible to the dioxide. Although the composition of the precipitate was inconstant, it had a high molecular weight, and was easily filtered and ignited to the oxide at 700°–800° C. Elements such as iron, tin, titanium and zirconium gave insoluble precipitates with the oxalic acid and these interfered with determination.

Tetraphenylarsonium Chloride for Tellurium

A 0·02 M solution of tetraphenylarsonium chloride $(C_6H_5)_4AsCl$ has been used as a reagent for the separation and determination of tellurium and selenium[46]. With tellurium, a precipitate having the composition $[(C_6H_5)_4As)]$ $TeCl_6$ was obtained from 5 N hydrochloric acid. The precipitate was dried at 110° C. and weighed. Selenium did not interfere, but could be precipitated in the filtrate by means of sulphur dioxide. The high molecular weight of the compound gave a favourable conversion factor, and the determination could also be finished titrimetrically by using the pentavalent arsenic part of the molecule. Bromide, iodide, fluoride, molybdate, tungstate and nitrate ions interfered with the determination, as did metals such as mercury, tin, bismuth, iron, platinum and gold, etc., by formation of complex chlorides.

Trans–Dichlorobisethylenediaminocobaltic Chloride for Antimony

When a solution of trans–dichlorobisethylenediaminocobaltic chloride was added to a solution containing pentavalent antimony in hydrochloric acid, a precipitate of dichlorobisethylenediaminocobaltic hexachlorostibnate was obtained, which was insoluble in water and hydrochloric acid. The antimony content of the precipitate was only 20·98%. The compound was dried at 100° C. and weighed[47]. It could not be washed with acetone, ethanol or ether, in which media it was soluble. The time required for complete precipitation varied with the volume of the precipitation medium, being 2 hours in a final volume of 50 ml. and 6 hours in 100 ml. Several oxidants were employed to keep the antimony in the pentavalent state, but only gaseous chlorine and nitric acid were successful. The reagent was fairly selective, only lead interfering at all concentrations. Large amounts of arsenic, zinc, copper, iron, cadmium, tin and mercury did not interfere, and small concentrations of bismuth were similarly without effect. A procedure was developed for the analysis of antimony in white metals after a preliminary separation of the interfering elements. Generally speaking the method appears to be an attractive one. The conversion factor 0·2098 is much more favourable than those obtained with the time-honoured methods which employ weighing as the tetroxide or trisulphide. The use of gaseous chlorine is an unpleasant feature, but the alternative use of nitric acid as oxidant overcomes this objection. As is the case with most new gravimetric methods, the reagent is not commercially available. The authors do not comment on the ease of preparation of the compound.

o–Phenanthroline and Mercaptobenzthiazole for the Platinum Metals

Ryan[48] has shown that palladium forms precipitates with 1,10–phenanthroline and 2,2′ dipyridyl. In another paper, in conjunction with Fainer[49], Ryan used the former reagent for the gravimetric determination of palladium. Low results were obtained by the gravimetric finish on 16 mg. amounts of the metal, although complete recovery was obtained on 7 mg. amounts after ignition of the precipitate to the metal. High results were obtained in the presence of equivalent amounts of the other platinum metals. In a more recent paper, Ryan[51] has shown that in the micro-gravimetric determination of palladium by *o*–phenanthroline, a single precipitation was sufficient to separate the metal completely from rhodium, but a re-precipitation was required in the presence of platinum and iridium. The precipitate had a low palladium content, was of constant composition and was a suitable weighing form. Indeed the extreme stability of the precipitate allowed palladium to be separated from platinum without destroying the first precipitate, simply by dissolving in strong mineral acid.

Ryan and Fainer[50] have also developed a gravimetric method for rhodium using mercaptobenzthiazole as reagent. The precipitation of rhodium from 0·05 N nitric acid was complete, but an acetic acid medium was preferred because the control of acid concentration was then less critical. The precipitate was digested for 1 hour before filtering and ignition to the metal. The compound 2–mercaptobenzoxazole was also recommended as a reagent.

At this point attention should be called to the work of Beamish and his school on the determination of the platinum metals. These workers have made what must be regarded as a most valuable contribution to the analytical chemistry of this group of metals, by making a critical survey and examination of existing micro methods. Jackson and Beamish[52] have made a detailed examination of the conditions affecting precipitation of platinum as the sulphide, particularly with regard to chloride ion concentration. The efficiency of the various concentrations of ammonium chloride and hydrochloric acid used to leach the precipitate was evaluated, and an accurate procedure for the microgravimetric determination of platinum was outlined. Errors usually associated with the sulphide method were found to be positive. A later paper[53] discussed the merits of reduction with formic acid, reduction with zinc and precipitation as ammoniumhexachloroplatinate. Although reduction with formic acid was successful for amounts of platinum in the range 0·3–0·1 g. the results were insufficiently precise

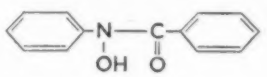
to be applied directly to the micro scale. The average recovery for 10 mg. samples was good, but the precision on individual results was poor: the spread was much more pronounced with 5 mg. samples. Beamish and co-workers comment that the persistent use of ammonium chloride as precipitant for platinum in spite of the well-known incompleteness of precipitation, can only be accounted for by its value as a separation method for platinum and iridium from solutions of base metals and the other platinum metals. Reduction with metallic zinc is not generally favoured because of contamination of the precipitate by the reductant. Results high by as much as 10% were found in separation from base metals. Leaching with hydrochloric acid is frequently used to counteract this tendency, but this results in low recoveries. Beamish and his co-workers obtained excellent results by replacing the leaching process by ignition in an atmosphere of hydrogen, thus volatilising the contaminant zinc. Yet another paper from the same source dealt with the separation of iridium from lead[54]. This was accomplished by two methods: (1) removal of the lead as phosphate with subsequent hydrolytic precipitation of the iridium, or (2) by direct determination of the iridium in the presence of the lead using 2-mercaptobenzothiazole.

Trithiocarbonic Acid for Copper, Zinc, Molybdenum and Antimony

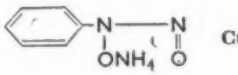
For several years, use has been made of thioformamide and thioacetamide for the homogeneous precipitation of the sulphides of various metals. For example, the former reagent has been employed for the precipitation of arsenic[55], copper[56], and copper and arsenic[57] in the presence of each other, and the latter for copper and arsenic[58] amongst other ions. To these two, Gagliardi and Pilz[59] have now added trithiocarbonic acid to the list of reagents used for the homogeneous precipitation of sulphides. Copper sulphide was readily precipitated in acid concentrations from 0·1 N to 6 N. The precipitate was easily filtered and washed, and the presence of chloride up to 4·6 N was not harmful. The acid sodium salt of trithiocarbonic acid was used by Pilz[60] to precipitate zinc sulphide from solution instead of hydrogen sulphide. The maximum permissible acidity was 0·02 N in mineral acid or 2 N in acetic acid. The zinc sulphide was readily converted to the oxide by careful ignition. Molybdenum in the hexavalent state was readily precipitated as sulphide by addition of sodium trithiocarbonate to the solution, which was diluted so as to contain 1 mg./ml. of molybdenum. The solution was sufficiently acidified with sulphuric acid to liberate the free thio acid, whilst keeping the acidity of the solution below 2 N. The solution was heated to boiling, and the precipitate ashed carefully for 2–3 hours at 500°–550° C. The authors[61] preferred to dissolve the precipitate and titrate with permanganate after reduction with zinc. The latest paper in the series describes the precipitation of antimony sulphide[62]. However, the authors again prefer to apply a titrimetric finish after solution of the trisulphide in hydrochloric and sulphuric acids.

N Benzoylphenylhydroxylamine for Copper, Iron, Aluminium and Titanium

N Benzoylphenylhydroxylamine which is closely related to the reagent cupferron, was shown to have several advantages over the classical reagent in a recent paper by Shome[63]. For example, it was indefinitely stable towards heat, light and atmospheric oxidation, it was soluble in hot water, formed granular precipitates with metal ions, and perhaps most important of all, the complexes formed with iron, aluminium and copper could be weighed directly.



N Benzoylphenylhydroxylamine



Cupferron

The titanium compound was ignited to the oxide as in all cases of precipitation with cupferron. Some ions, such as lead and mercury, which interfere with the cupferron determination of copper did not interfere when the new reagent was used. The interference of phosphate, arsenate and arsenite in the determination was overcome by addition of sodium potassium tartrate, but tin, zirconium, molybdate, tungstate and vanadate ions still gave precipitates with the reagent. Iron could not be separated from aluminium and chromium, and while titanium was readily determined in the presence of aluminium, iron and phosphate interfered seriously. Shome used an ethanolic solution of the reagent, adding it to a hot solution of the metal ions being determined. The *p*H of the solution was adjusted by addition of the requisite amounts of 10% sodium acetate or N H_2SO_4. Precipitation of copper was complete between *p*H 3·6 and 6, while the ranges for iron and aluminium were 3–5·5 and 3·6–6·4 respectively. The iron and aluminium precipitates formed into hard lumps when thrown down at temperatures above 70° C., and hence precipitation was effected at 65° C. Titanium must be deposited below 25° C. in order to avoid the formation of a gelatinous mass, and it must be deposited at a slightly higher acidity than is used for the other metals. The precipitates were dried at 110° C. and weighed as $Cu(C_{13}H_{10}O_2N)_2$, $Fe(C_{13}H_{10}O_2N)_3$ and $Al(C_{13}H_{10}O_2N)_3$. The precipitates were green, red and white respectively, and melted with decomposition at 198°, 187° and 238° C. They were also decomposed by moderately concentrated mineral acids, and were soluble to a certain extent in various organic solvents. The conversion factors were aluminium 0·04064, copper 0·1303, and iron 0·08064. All three precipitates could be weighed directly after precipitation, even in the presence of Be, Co, Cd, Mn, Ni, U^{VI} and Zn. Shome's reagent appears to be superior to cupferron for dealing with small amounts of these metals, since ignition to the oxide is unnecessary and a better conversion factor is obtained.

Tetraphenyl Boron for Potassium

Raff and Brotz[64] have used the sodium and lithium salts of tetraphenyl boron as a precipitant for potassium. The potassium compound $K[B(C_6H_5)_4]$ containing only 3·787% of potassium was shown to be only 0·1% as soluble as silver chloride, and was stable to drying at 120° C. In the procedure described, up to 100 mg. of potassium in 100–200 ml. of water were treated with acetic acid, and a 50% excess of the precipitant. The precipitate was filtered after 5 minutes, washed with very dilute acetic acid, and dried at 120° C. In the presence of alkaline earths it was found best to precipitate these

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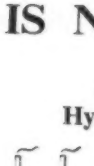

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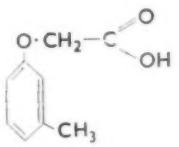
with sodium carbonate, add the reagent, and then dissolve the alkaline earth carbonates in acetic acid. This procedure prevented co-precipitation of the alkaline earths. Flaschka[65] subsequently adapted the method to the micro determination of potassium, obtaining good results on 39–39·5 μg. amounts. A 3% solution of the sodium salt was used as reagent, and the precipitation was effected at 70° C. Rudorff and Zannier[66] pointed out that the precipitation of potassium with the new reagent was unhindered by relatively high concentrations of aluminium or chromium, while the interference of iron was overcome by complexing with fluoride. They indicated that the slow settling of the potassium precipitate which was an unpleasant feature of the original method, could be overcome by adding aluminium chloride to the solution. Under these conditions, the potassium precipitate was readily filtered through an ordinary filter paper, for the purpose of developing a titrimetric finish. However, although they set out to achieve a titrimetric finish and achieved their object in so doing, the procedure recommended appears to be complex and the simple gravimetric method is probably more trustworthy. The reagent is new, and no true assessment can be made of its value yet. It is not available commercially, but this will probably be remedied in time, as the method appears attractive.

m–Cresoxyacetic Acid for Zirconium

The increasing use of zirconium in alloys has been reflected in recent developments in the analytical chemistry of zirconium. *m*–Cresoxyacetic acid is superior to, and was adumbrated by, a series of aliphatic and aromatic carboxylic acids examined and proposed by Rao and his school for the gravimetric determination of zirconium. The series included phthalic acid[67], benzilic acid[68], cinnamic acid[69], salicylic acid[70], fumaric acid[71], phenoxyacetic acid[70], and *m*–nitrobenzoic acid[72,36]. These acids precipitated zirconium under varying conditions of acidity and dilution, etc., but a common feature was that, in all cases except benzilic acid, the precipitates were converted to the oxide as they were of inconstant composition. The phthalic acid

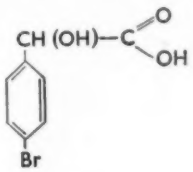


m-Cresoxyacetic Acid

reagent (4% solution) separated zirconium from Al, Be, Fe, Mn, Ni, Th, U and the cerite earths in a single precipitation, but a re-precipitation was necessary in the presence of chromium, tin and titanium. In the case of benzilic acid the authors found that the precipitate could be weighed as $[(C_6H_5)_2C(OH)CO_2]Zr(OH)O.4H_2O$ after drying at 110° C., but they preferred to ignite the precipitate and weigh as the oxide. *m*–Cresoxyacetic acid was found to separate zirconium from Al, Be, Ca, Ba, Ni, U and the rare earths. The precipitation was quantitative from 0·2 to 0·25 N hydrochloric acid, and the deposit was bulky and settled quickly. As little as 2 mg. of ZrO_2 was easily handled. Tin, titanium and chromium which were not themselves deposited by the reagent at the acidity employed for zirconium, were co-precipitated in the presence of the latter.

p–Bromomandelic Acid for Zirconium

In 1947, Kumins[73] demonstrated that zirconium could be precipitated completely from hydrochloric acid solution, using mandelic acid as precipitant. The reagent was fairly selective, aluminium, chromium, titanium and vanadium not interfering. The determination was also carried out in sulphuric acid solution when its concentration was less than 5%. Partial neutralisation of sulphuric acid in excess of this, using ammonia, still caused low recoveries, but sodium hydroxide could be used. The precipitate was ignited to the oxide. Hahn[74] re-examined the reagent, adapting it to the micro scale, and showing that cobalt, nickel and zinc did not interfere. Oesper and Klingenberg[75] showed that the *p*–chloro and bromo derivatives also gave quantitative precipitation of zirconium. These reagents



p-Bromomandelic Acid

showed a greater sensitivity than the original mandelic acid. The precipitates could be washed with water and did not require to be ignited to the oxide, although ignition was preferred because difficulty was experienced with solutions containing metals other than zirconium. The bromo acid was preferred to the chloro acid, and both were preferred to mandelic acid. In weighing the precipitate directly, it was dried at 100° C. for 15 minutes after washing with distilled water several times and twice with ethyl alcohol. Klingenberg and Papacci[76] have recently applied the method to the determination of zirconium in high silicon steels. The presence of selenium was found to discolour the precipitate, but the analysis was unimpaired. Hahn[77] has made a critical investigation of the reagent and recommended it for the determination of hafnium in the presence of zirconium. The combined *p*–bromomandelic acid precipitates were weighed and ignited to the oxides and re-weighed. Solution of the simultaneous equations gave the hafnium/zirconium ratio. Precipitates of theoretical composition were obtained only in hot solutions made strongly acid with hydrochloric acid in the presence of a two- to three-fold excess of reagent. Inclusion of aluminium, iron or titanium ions in the solution caused erratic recoveries. The reagent has been used fairly extensively in this country, and although it is generally recognised as being an advance on Kumin's reagent, there seems to be doubt as to the advisability of weighing the precipitate directly.

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